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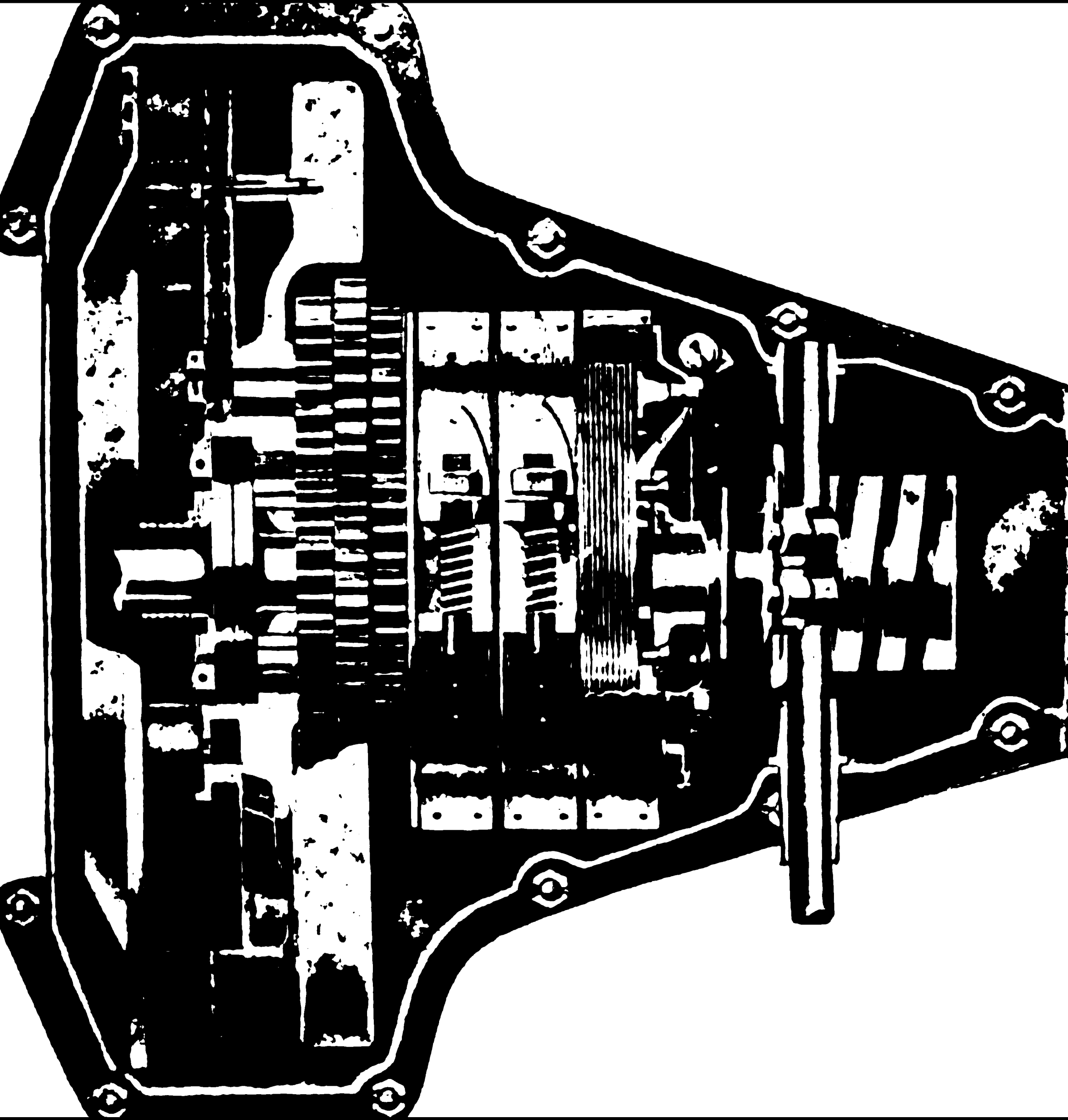

The gasoline automobile

Victor Lougheed, Morris A. Hall

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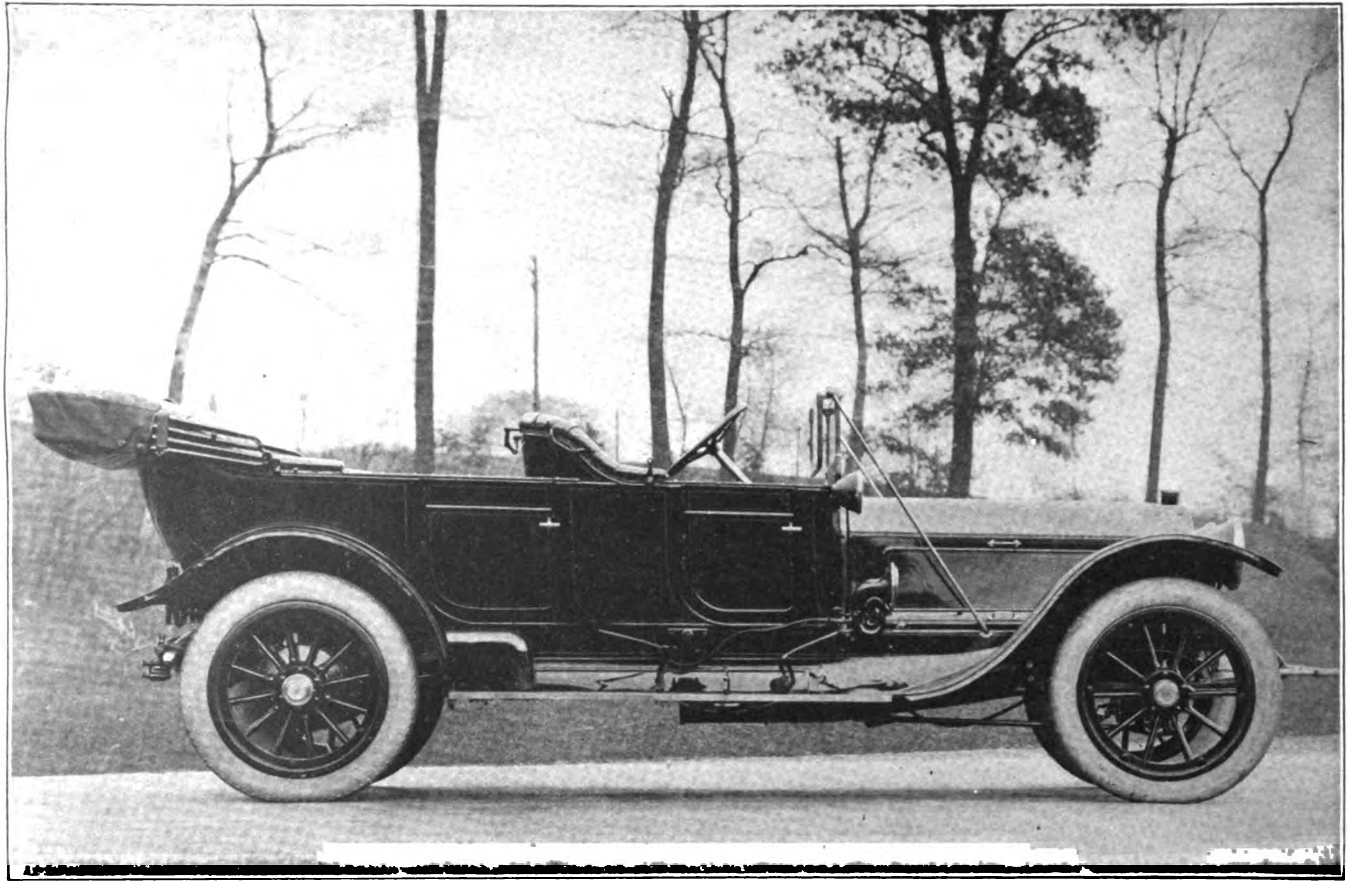

PEERLESS 60-SIX SEVEN-PASSENGER TOURING CAR
The Peerless Motor Car Company, Cleveland, Ohio

THE GASOLINE AUTOMOBILE

A PRACTICAL DISCUSSION OF THE DEVELOPMENT AND PRESENT STATUS OF THE AUTOMOBILE

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1912

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INTRODUCTION

THE automobile is today such an important part of our business and our pleasure, that we as an intelligent people should be interested in learning more about this marvelous collection of mechanisms than can be derived from an examination of the "works" or even from experience in running the car itself. A little investigation of the explosion motor will show that there is no mystery connected with the admission, compression, explosion, and expulsion of a small charge of gas in each cylinder about ten times every second. Everything is as systematic and orderly as the laws of nature, and it is this very orderliness which demands of every mechanism that it perform its little function in the cycle of operations without variation. It has been said that "a little knowledge is a dangerous thing," but the little knowledge which enables the experienced chauffeur to tell that his carbureter has a grain of sand in it, that the spark plug of the third cylinder needs fixing, that one valve is not seating properly, or that a pin connecting the throttle mechanism has dropped out, might help you, gentle reader, to avoid an awkward situation and keep your car on the move. Anyone can be a good driver if the motor runs without a falter, but sometime, somewhere, that person is going to be called upon for the "know how." Has he got it?

¶ The publishers of this book do not claim it to be a compendium on the gasoline automobile, but have designed it to meet a need for an authoritative and readable presentation of the essential elements of the gasoline motor and its attachments, a discussion of the newer features of the modern car, and helpful suggestions regarding road and home repairs.

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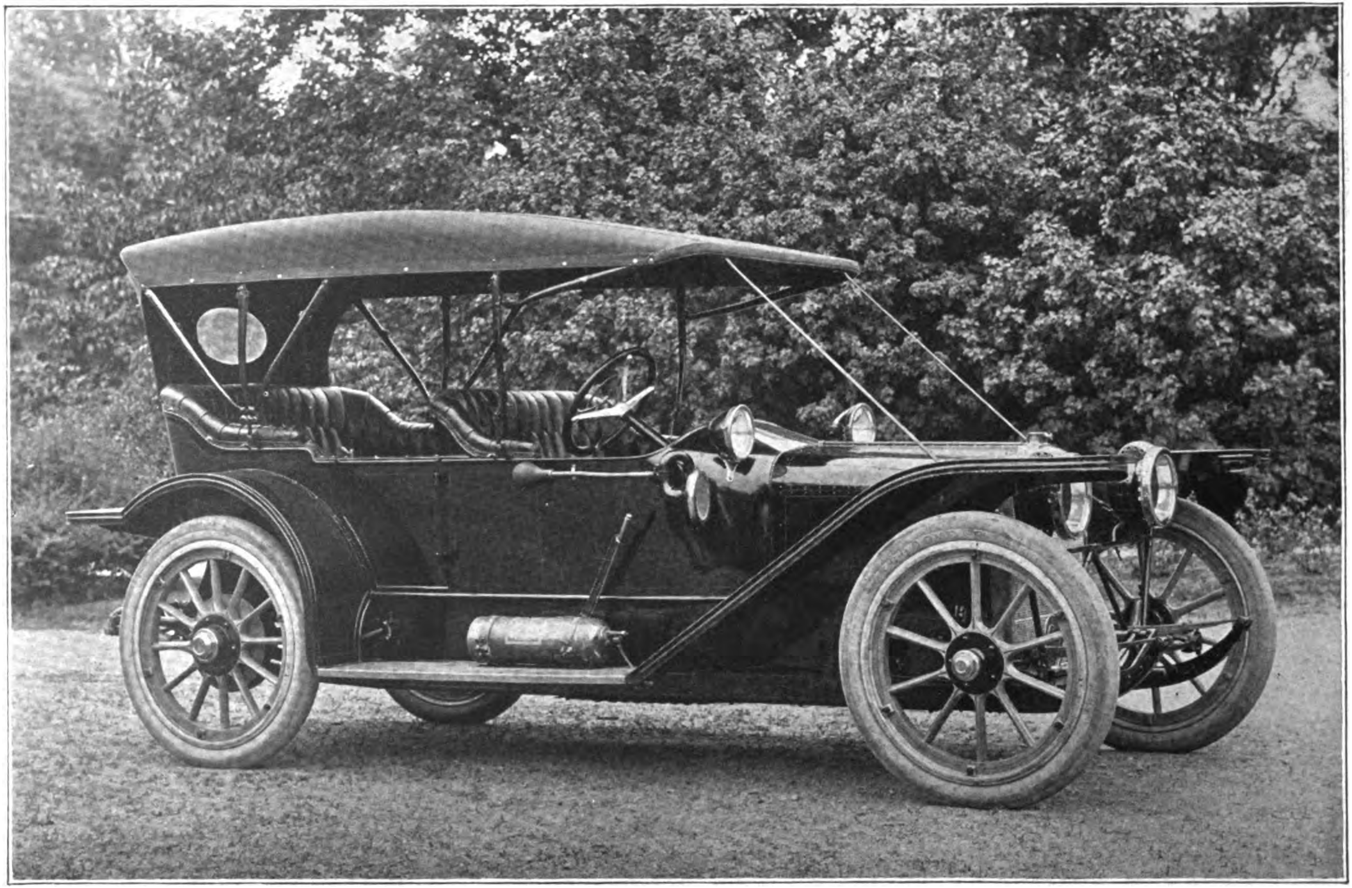

THE AMERICAN TRAVELER UNDERSLUNG TOURING CAR
American Motors Company, Indianapolis, Indiana

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GASOLINE AUTOMOBILES

PART I

INTRODUCTORY

Of all the applications of the internal-combustion motor, it is safe to say that none is more important than that applied to the propulsion of the modern motor vehicle—the automobile, which nowadays throngs the roads and streets of all civilization, serving a myriad of utilities as they never have been and never could be served by animal transportation.

Standardized, inexpensive to buy, and inexpensive to operate, almost unfailingly reliable, and proved capable of use in the hands of even the most unmechanical of operators, the automobile is at last coming fully into its own—its design becoming recognized as a branch of engineering by itself, its manufacture constituting one of the greatest of the mechanical industries, and its use being a common necessity.

Naturally, in so tremendous a development, there is sustained by the general public every possible sort of relationship with the new conveyance, from that of the merely casual observer or occasional user to the more interested owner, and thence on, in ever closer and closer touch with the full significances of this field of engineering, to the high-skilled and well-paid drivers of cars, the experts who repair them, the shopmen who build them, and the engineers and draftsmen who design them.

All along this line there is a crying need for knowledge—a demand for definite, specific, usable information concerning the science upon which the motor vehicle is based, and the practice upon which its construction and performance are founded.

With regard to no other field of engineering of similar importance—in which there is invested anything like a similar amount of capital, or in which there are anywhere near as many people inter-

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ested—is there such a lack of correct and authoritative literature as in the automobile field.

This undoubtedly is due to two conditions that have been involved in the rapid growth of the automobile from a mere experiment to an achieved and commercial fact. First of these conditions is the circumstance that the men who have most studied the automobile from an engineering standpoint, and who are best informed about it, have not been allowed the time to place upon paper the facts with which they are acquainted. The second condition—automobile design and engineering practice having developed so rapidly—has been the lack of time for the establishment of a formulated science, founded upon tabulated knowledge, upon which to base textbooks of a genuine and permanent authority.

It is these conditions, prevailing until within a very recent period, that render it reasonable to assert that the present course is absolutely the first printed matter in which text and illustrations are not only up to the minute in accuracy and completeness, but in which there is embodied the further certainty of substantially meeting the needs of students of this subject for some time to come.

In what follows, for example, will be found advanced and comprehensive treatment of the very latest devices that are applied in automobile engineering, all carefully described and their essentials fully analyzed, and with their important details fully illustrated.

PAST AND PROSPECTIVE DEVELOPMENT

Credit for the first conception of the automobile has been variously accorded to many men and to many countries.

Dismissing, as without proper place in a work of this character—however interesting these may be from other standpoints—the various wholly or semi-mythical accounts that have come down from past ages and ancient civilizations concerning self-propelled vehicles, the real fact seems to be that the modern automobile was almost simultaneously conceived in both Europe and America.

Thus in France there was the work of the inventor Cugnot, who in 1804 sought to provide Napoleon's armies with steam-driven tractors for towing gun carriages, and who built and operated with some success a first model on good highways.

In the United States, practically contemporaneous with the foregoing, was the curious amphibious vehicle of Oliver Evans, which is declared to have moved by its own power, not only in the water, but on the streets of Philadelphia.

A particularly interesting and curious phase in the development of the mechanically-propelled road vehicle was the exploitation of steam coaches, built by a number of different inventors, and in a considerable proportion of cases experimented with on the highways of England with marked success, during the early years of the last century.

Following these, the traction engine, which despite its low speed is a close relation of the automobile, entered upon a period of steady development that has not yet ceased. And consistently, during the earlier period of its development, was there from time to time revived and struggled with an ideal of a faster, lighter, and more easily controllable vehicle, which should be capable of operation by the average individual, and which should take the place of the horse.

Occasionally automobiles that were virtually miniature traction engines were built and run, but this sort of experimenting did not prove the road to a solution. And little improvement resulted even when several of the more prominent pioneers, particularly in Austria, Germany, France, and the United States, began to turn away from steam and look to the then newly-developed internal-combustion engine as the source of the necessary motive power.

But the reason for the failure of these early efforts was not so much because of the lack of a proper source of power as because of a failure to appreciate the fact that fast travel on imperfect highways was not possible without some more perfect tire than any invented up to that time.

Then came the bicycle, which, likewise dating from the early years of the century, because of its weight, clumsiness, inefficiency, and other limitations, long occupied the status of a toy rather than that of a practical device. The bicycle, therefore, had developed only at a very slow rate, quickened somewhat by the application to it of ball bearings and given a further impetus by the application of the solid-rubber tires, but the fundamental quality was still lacking.

This entered with the advent of the pneumatic tire.

Almost within weeks after their first exploitation, pneumatic tires were practically tested. The bicycle advanced from the toy to a recognized necessity. Rendered simple by its very limitations—its size determined by the size of the average man, its weight determined by the weight of the average man, and its speed a function of the muscular energy of the average man—the bicycle required only a few years to evolve it to a seemingly almost final standardization, as well as to degrees of mechanical perfection and manufacturing economy that the wildest enthusiasts had hardly dared to hope for a few years earlier.

In the meantime certain matters had been made evident. The bicycle, with its pneumatic tires, having shown how to secure a maximum effect from a minimum of power—the utmost of efficiency and speed with the least energy—it was a most obvious sequence to turn again from muscular power to mechanical energy for means of propulsion.

The first result was a brief period of prominence for steam-propelled "horseless carriages," but this freak development gradually subsided, leaving the gasoline engine in all but undisputed possession of the field.

Among the first, and by many considered the greatest, of the real pioneers of modern automobiles, the name of Gottlieb Daimler must forever rank high.

Commencing with a motor bicycle, Daimler was undoubtedly the first man to realize in any especial degree the possibilities of gasoline-engine design as applied to high-power and light-weight construction. And as founder of the great Daimler Company, in whose famous Mercedes automobiles there were first applied the float-feed carbureter, the long-stroke motor, the pressed-steel frame, annular ball bearings, the honeycomb radiator, and a host of minor improvements that subsequent general adoption proved of basic importance, Daimler's claim to the most that his admirers have asserted for him is hard to dispute.

Other important contributions to automobile engineering were wheel steering and the sliding gear, first applied by Panhard and Levassor, of France, and electric ignition, the early development of which was largely in the hands of the Marquis de Dion of France.

With first principles established and practical features of construction demonstrated, the age of the automobile was fully begun. Unfortunately for the credit of America, however, the incomparable superiority of European roads resulted in all of the most important and advanced development work being carried on abroad, so that the modern motor car had its evolution well under way and its type fully fixed long before American business men began seriously to regard it as a device of commercial importance.

The result was that the United States, as the greatest market in the world for automobiles—possessing both the territory to create the need and the wealth to supply it—has been able to seize only the belated but perhaps not less important distinctions of producing more automobiles than all the rest of the world combined and of building high quality cars at the very low prices permitted by the efficiencies of quantity production.

Today the business of building automobiles is as settled and conservative as any other manufacturing business that exists. Automobiles are no longer regarded as freaks or fads, or as of questionable utility. And not alone do they serve pleasure uses—pleasure being, after all, one of the highest forms of utility—but the modern automobile is rapidly entering permanently into fields that, even long after its improvement to the point of successful utilization for some purposes, still remained closed to it.

But today the automobile delivery wagon and the motor truck are fast emancipating the beast of burden, and, against the once oft-proclaimed reliability of the "good old-fashioned horse," it now has almost ceased to be a matter for comment, that on sleety winter days and during blizzards, when horse traffic is almost hopelessly handicapped, and even street and elevated railway systems go out of operation, the automobile is the one vehicle that remains unfailingly in service, little troubled by the elements that prove so disastrous to its competitors.

In just what directions the automobile of the future is to be most improved it is hard to say. But, if prophecies are dangerous, analogies may be safe, and it seems at least reasonably certain that the recent disfavor commencing to be visited upon the poppet valve, and which already has found practical expression in the conspicuous successes of sliding-sleeve valves, will not end until the poppet valve has completely disappeared. With it will go few regrets, for in the modern gasoline engine it is one of the few elements left that work for unreliability, trouble, low power, and frequent attention.

That the place of the poppet valve is to be taken, however, by the sleeve-valves that slide between piston and cylinder is not yet to be admitted, and does not necessarily follow from the progress that has been made with valves of this character. This is because there are important rotating, oscillating, and sliding-valve constructions, which have been developed from time to time in the history of automobile engineering, which still await fair trial to determine their possibilities. Among these, if the opinions of many prominent engineers are of any value, there undoubtedly exist the germs of more than one meritorious construction. Indeed, it is not too much to expect, as the various possibilities are exhaustively investigated, that it will be found, as in other branches of mechanical engineering, that there always are many methods of realizing a desired result.

More important even than the abatement of the valve question is the problem of cooling. The worst remaining feature of the barbarous age in automobile engineering undoubtedly is the water cooling. That water cooling does not remain without reason, that it is extremely hard to dispense with, and that, in fact, the problems of successful air cooling from the standpoint of all sorts of uses do present difficulties almost insuperable—these are no controversion of the statement made. For water cooling adds complication and subtracts reliability, multiplies cost, and increases attention.

Indeed, water cooling is too effective to be good, it being, in fact, a recourse to the other extreme from air cooling. For the object really sought is not to keep a gasoline engine as cool as possible, but to run it as hot as it is permissible, a condition that renders overcooled motors almost as bad in one direction as are overheated motors in the other. Perhaps the extreme opposite of air cooling was Daimler's use of ice in the jackets of the cylinders in the course of some of his first experiments with a motorboat motor; yet this was a condition, at that, rather closely paralleled in the winter use of most modern automobiles, in which the cooling water is often very close to the freezing point—perhaps even below it if an anti-freezing solution is used.

In consideration of the foregoing, no engineer who has any regard for facts can refuse to admit that water cooling is undesirable, and that it is no more than a reasonable expectation based upon past achievement in mechanical engineering that technical science will in time solve the problem of operating an automobile motor continuously without the expedient of surrounding it with a refrigeration plant connected to it by a system of plumbing.

And certainly the layman, who may chance to observe four and five thousand dollar cars standing on the streets in winter with blankets and buggy robes placed over their bonnets, will scarcely be disposed to accept this as finality in engineering.

While the way to successful air cooling is not as obvious as is the fact that sooner or later it must be traveled, it would seem, nevertheless, that all possible schemes of fin and flange combinations with blowers, fan, and air jackets to force over them a maximum quantity of air, have been exhaustively tried out.

This would leave, as the only further recourse, cooling by internal scavenging—by blowing blasts of air through the interior of the cylinders at neutral points in the cycle. Cooling of this type is receiving increased consideration, because of a few conspicuous successes it has achieved in aviation-motor development and some in stationary and automobile practice. Without going into details at this point there are many reasons for expecting internal scavenging to prove the one definite and practical way, without water cooling, to secure thoroughly efficient working conditions, avoiding both overheating or overcooling in an automobile motor.

Of the elements of a complete automobile outside of the power plant, probably the most interesting among the more recent developments are the increasing use of silent chains for driving cam shafts, and to some extent in gear boxes and the final drive; the use of worm instead of bevel gears for the final drive—a result of the present tendency towards higher rotational speed in motors; and the prospect of reversion from wood to wire wheels.

Among improvements of secondary rather than of fundamental importance are the practical systems of electric lighting that are now available, and the many very effective self-starters and automatic-cranking devices that are coming into use.

Not the least of automobile improvement has been in bodies which, instead of continuing to follow slavishly the patterns developed by coach builders for horse vehicles, are now commencing to assume distinctive character and individuality adapting them strictly to their proper status as elements of a power-propelled rather than a horse-drawn conveyance.

BODIES

As the portion of an automobile that provides the accommodation for the passengers, or that contains the merchandise to be hauled, as the case may be, the body is a most important element, well worthy of all of the study that can be expended upon its problems.

As is suggested in a preceding paragraph, the motor vehicle, for its fullest usefulness, requires bodies fundamentally designed for it rather than adapted for it from other constructions. Only by growing recognition and application of this fact has it been possible for the automobile of all types—pleasure and commercial—to develop to its present practical status.

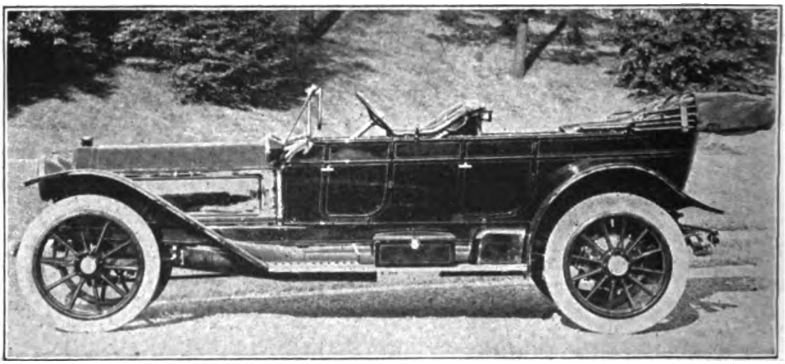

Fig. 1. Typical Torpedo Roadster, Peerless "48 Six"
Peerless Motor Car Company, Cleveland, Ohio

Pleasure Bodies. Under this heading are usually grouped all types of open and closed bodies used for the conveyance of passengers, with the exception of omnibus bodies, which ordinarily are mounted on truck chassis and used for the conveyance of passengers on urban and suburban routes. The slight confusion in terms that results, involving, for example, the classification of such public service vehicles as the taxicabs of modern cities under the heading of "pleasure cars," is an incongruity that perhaps has been already sufficiently dismissed with the statement previously made, that pleasure is a high type of utility.

Open and Enclosed Bodies. These embrace, in their standard forms, the various established types of the roadster—for carrying usually only two persons, though sometimes provision is made for another at the rear or one side; the touring car, for four to seven passengers; the coupé, for from two to four passengers; the limousine, for seven passengers and sometimes even more; the landaulet, similar to the limousine, except that the top is capable of folding; and the berline, similar to the limousine, except that the driver's seat is completely enclosed. A typical torpedo roadster of modern type is illustrated in Fig. 1.

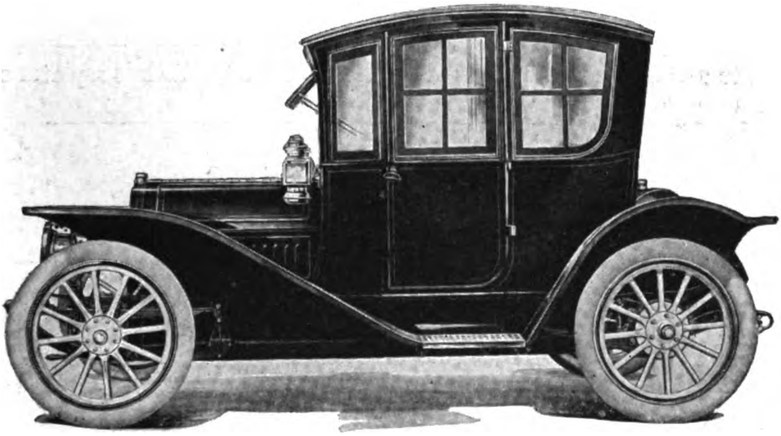

Fig. 2. Regal Model "H" Underslung Touring Car
Regal Motor Car Company, Detroit, Michigan

A particularly neat example of the coupé body on a very moderate-priced American car is that illustrated in Fig. 2. This car, which is built with an underhung frame, sets very low, without, however, involving a low road clearance. The result, besides an unusually sightly appearance, is exceptional accessibility and comfort.

Similar bodies are built by other manufacturers, and the Colonial effect of the small windows has been found to lend itself to a number of most pleasing combinations.

Fore Doors. Doors similar to those long used beside the rear seats, but applied between the sides of the front seats and the dashboard, are almost universal on modern open cars. Besides making for warmth in winter and the exclusion of dust in the summer, they also adapt themselves especially well to incorporation in the lines of torpedo and other popular recent body designs of more or less stream-line form.

Stream-Line Forms. These forms, which aviation research has proved to be the correct ones for bodies to move through air with a minimum resistance and disturbance, have been more or less successfully applied to many automobiles, in the shape of torpedo and similar bodies, of one design and another, in which it has been sought to incorporate, as fully as conditions will permit, certain of the more marked advantages of these forms.

An extreme but quite successful application of the stream-line form to an automobile body is illustrated in Fig. 3, which is a picture of the Marmon "Wasp," and which has achieved, with very moderate power, a most enviable record in various races and competitions held within the past year or so in the United States.

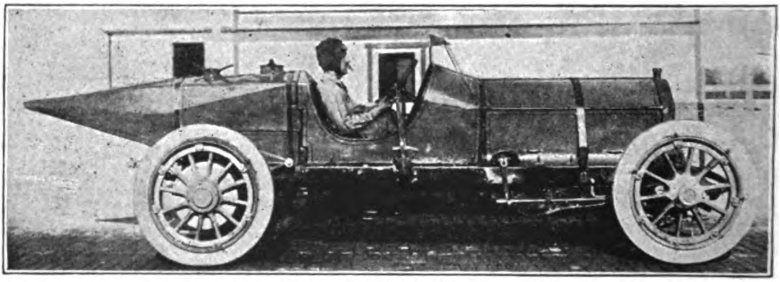

Fig. 3. Exaggerated "Stream-line" Body, the Marmon "Wasp"
Nordyke-Marmon Company, Indianapolis, Indiana.

The particular effect of a stream-line form of this type, with its long tapering rear, is to secure a definite propelling pressure resulting from the elastic masses of parted air springing together again upon the tapered rear, and thus returning a portion of the energy expended in overcoming the head resistance.

In the case of the automobile illustrated in Fig. 3, it is estimated that there is a saving, at high speeds, of as much as 30 horsepower.

The more practical advantage of the stream-line form, from the standpoint of the average user who is not directly interested in the phenomena of high resistances at high speeds, inheres in the fact that the same conditions that reduce air resistance also reduce air disturbance, and so avoid stirring up as much dust as is raised by ordinary bodies.

Tire, Battery, and Tool Storage. The problem of storing away the various impedimenta that a motorist must carry is one of those that for long was dismissed with scant attention, because of the greater importance of more serious problems with which the automobile engineer was faced. Now, however, there is a commendable tendency to provide in a practical and workmanlike manner for the stowing of extra tires, batteries for ignition or illumination, and such tools as it is well to have always with the vehicle.

Recent progress in the matter of tires has made the tire-storage problem evolve into really a wheel-storage problem, since most motorists, who know what is what, will not nowadays use a car without removable wheels or demountable rims, which enable replacements to be made on the road and repairs at home.

One much-favored way of carrying one or two extra tires is to strap them to brackets on the running board on the driver's side. Another is to carry them in brackets at the rear, an arrangement nicely adapted to runabouts, but not so convenient if it is also desired to carry a trunk at the back of the machine. With limousines and coupés, it is not unusual to place the tires on the roof.

Battery and toolboxes have in times past, and do still to a great extent, encumbered the running board, but the policy of placing them completely inside the body, or, as in a few instances that have appeared recently, in pockets built into the apron between the running board and the frame sill, has many features to recommend it.

Commercial Bodies. Automobile bodies for commercial uses range from the simplicity of the flat platform truck to the expensive and elaborate closed bodies used for automobile omnibuses.

An exceptionally capacious and well-designed type of motor omnibus is that illustrated in Fig. 4, which illustrates a type of vehicle capable of carrying thirty passengers, which is in general and successful use on the streets of Paris.

In Fig. 5 is shown a typical French motor truck, of five tons capacity. It is mounted on cushion rubber tires, doubled on the rear wheels. This truck, as also the one illustrated in Fig. 6, achieved a notable success in a recent French competition of commercial vehicles, in the course of which these machines were required to traverse hundreds of miles of ordinary highways, fully-loaded, and run under ordinary service conditions.

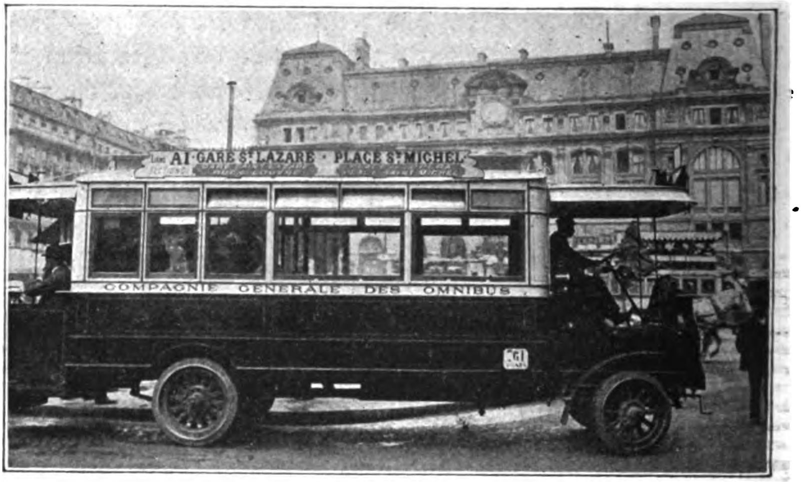
AI GARE S^T LAZARE · PLACE S^T MICHEL
COMPAGNIE GENERALE DES OMNIBUS

Fig. 4. Thirty-Passenger Motor Omnibus
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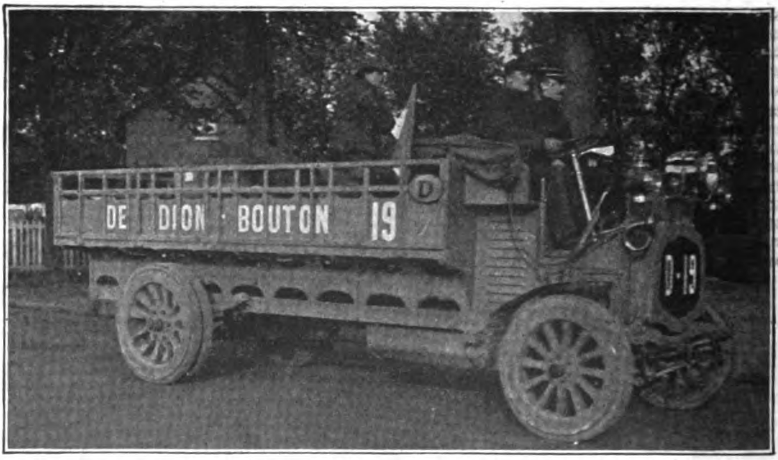

Fig. 5. Typical French Five-Ton Motor Truck
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The motor truck illustrated in Fig. 6 does not differ materially from that in Fig. 5, except that the body is different and double-chain drive is employed.

A most unique motor vehicle is that illustrated in Fig. 7. This machine, of a type of which a number have been manufactured for the French army, is mounted with a quick-firing gun that can be got into almost instant action, for use in line-of-battle, for harassing small bodies of troops, or for bringing down aeroplanes. In marked contrast to the generality of heavy automobiles, it is driven by a very high-power motor, is carried on pneumatic tires—double on the rear wheels—and is capable of very high speed.

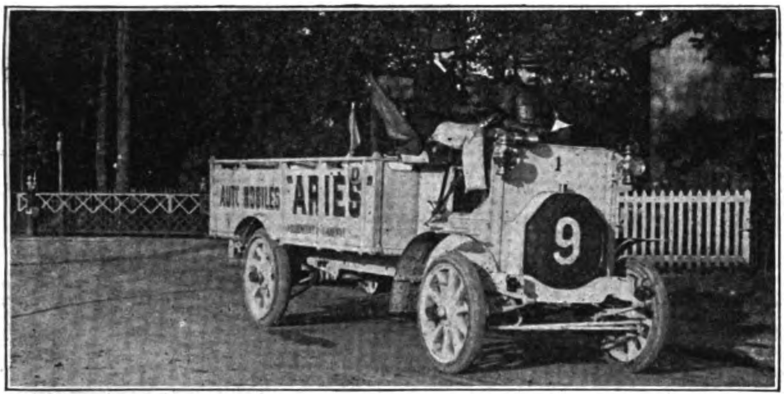

Fig. 6. Successful Type of French Chain-Driven Motor Truck
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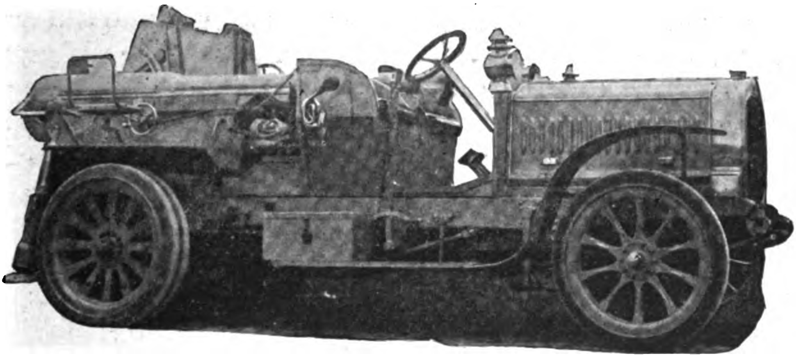

Fig. 7. French Military Truck for Carrying Cannon
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Interchangeable Bodies. Particularly from the users of small delivery wagons—the tradespeople in the smaller cities and towns—there is commencing to be heard a demand for interchangeable bodies, permitting the use of a single chassis for pleasure use when desired, and for commercial or delivery service when required.

The many different automobiles on the market are built on a much smaller number of chassis, and there are even prominent manufacturers who devote their entire activities to the construction of one type of chassis, to which they fit a variety of bodies. The result is that the interchangeable body is more generally available than is commonly supposed. That there is a big future before it is evident from the most casual analysis of needs and demand, and manufacturers are finding that it pays to cater to this demand by bending every effort to simplify and facilitate the interchange of the different body types.

RUNNING-GEAR ELEMENTS

In arranging a logical presentation of the multifarious details that combine to constitute modern automobile engineering, it is convenient to treat the running gear as distinct from the body, the power plant, and such portions of the mechanism as are involved in transmitting the power from motor to wheels.

Frames. The part of an automobile to which all other parts are attached, or upon which they all depend, is the frame. In most modern machines—though wood and steel tubing were much experimented with in earlier years—the frames are made of pressed steel, built up of two side sills formed up in channel section, and then connected by cross-members of similar section, riveted or autogenously welded with liberal gusset plates in the corners.

The most approved of present practice demands that the depth of web and the thickness of material vary with the size of the machine, from the thin and small sizes used for light pleasure cars up to the massive steel beams employed in the heaviest trucks. It is also usual for the frames to be narrowed at the front, to permit greater lock to the wheels for short turning, and a drop between the axles is generally desirable to allow liberal spring action without placing the body unduly high.

The underhung frame, of the type illustrated in Fig. 2, is coming increasingly into vogue for pleasure cars because it permits low placing of the body in combination with high road clearance. It also simplifies certain problems connected with the placing of the springs and axles.

Springs. Even on the smooth surface afforded by steel rails, a vehicle running at high speed will quickly pound itself to destruction unless as much of the weight as possible above the wheels be carried on yielding springs, to cushion the shock between wheels and load. Particularly necessary then, in an automobile, which must run on rough roads, is the provision of the most responsive, elastic, and durable springs that can be made.

Leaf Springs. This is the familiar type of spring, in almost universal use on automobiles and horse vehicles and extensively employed in railway cars. Properly proportioned to the loads they have to carry, and suitably and securely mounted, leaf springs afford all the spring action that can be desired and, if made of the best alloy steel, their breakage is very infrequent.

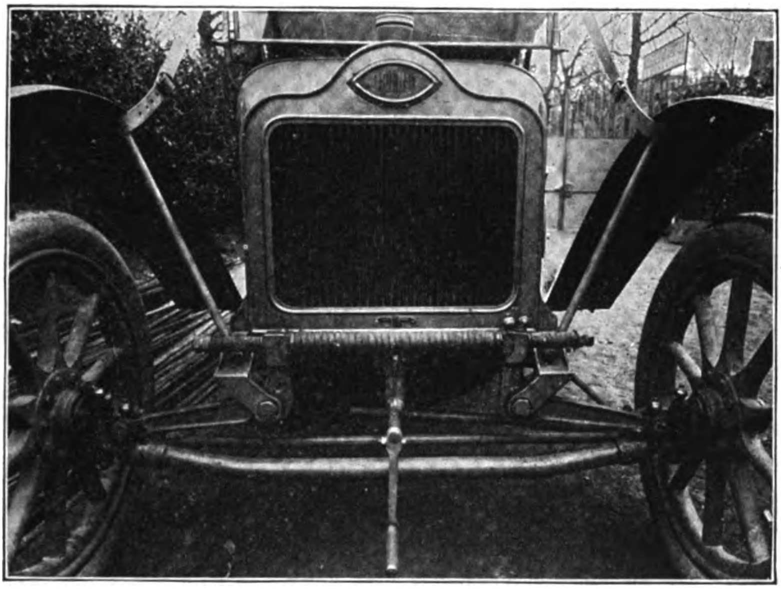

Fig. 8. Front View of Car Showing the Use of Helical Springs

Present automobile practice favors the half-elliptic spring, though the use of three-quarters elliptic and platform springs at the rear of cars is not uncommon.

Coil Springs. Springs of this type are of less present importance than they are of future promise. The great advantage of coil springs is that their smaller and compacter size renders practicable the carrying of one or two extra springs in a toolbox, in addition to which, if properly designed, they can be relied upon to afford a most perfect action. That there are no difficulties in the way of making coil springs of sufficient size for automobiles is abundantly attested in the fact that they are used on pullman and other railroad cars quite commonly. The first maker to apply coil springs successfully to automobile use was the Sizaire-Naudin concern of France. In this country the leading and practically the sole exponent of the coil spring idea is the Brush Company. The helical springing of a popular French voiturette is illustrated in Fig. 8.

Fig. 9. I-Beam Axle and Connecting Rod of Detroit Car
Anderson Electric Company, Detroit, Michigan

Axles. Automobile axles, like all other elements of the automobile, demand for the best results the best of materials and of workmanship. That these are especially necessary in axles, however, is due to the fact that axle failure is almost certain to result in serious accident.

I-Beam Axles. This is the term applied to the common forged or cast type of axle with a cross section like a capital letter I. The best axles of this type are forged from high-grade alloy steel, as in the example illustrated in Fig. 9.

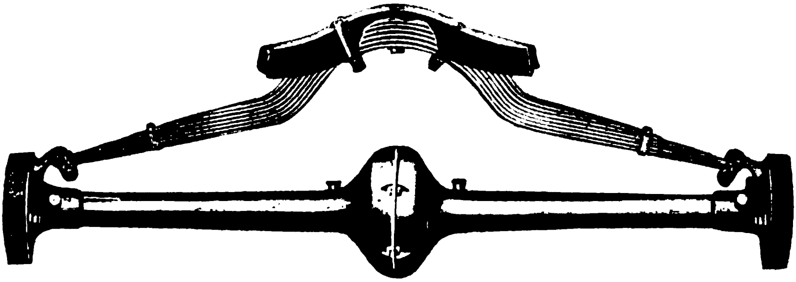

Fig. 10. Inverted Semi-Elliptic Rear Axle Springs Used in Ford Cars
Ford Motor Company, Detroit, Michigan

Pressed-Steel Axles. Steel stampings, assembled by riveting, bolting, or welding, are found widely serviceable for automobile rear-axle housings of the types through which the wheels are driven by the combination of propeller shafts, gears, and floating inner-axle members.

An axle that is one of the cheapest to produce, one of the strongest in service, and which perhaps demanded as heavy an initial investment as any in the preparations for its manufacture, is that illustrated in Fig. 10. This axle, which is used on a well-known American car, is made in two parts, each stamped and drawn out of a steel disk, and the two elements then joined at the center by bolts.

Particularly ingenious in connection with this axle is the use of a transverse rear spring, by which the load of the vehicle is carried almost into the plane of the wheels, so that it imposes only the very slightest bending strain on the axle.

Tubular Axles. Axles made of steel tubing, either with or without the reinforcement of a vertical strip of steel pressed into them, have been extensively used in the past by the various automobile manufacturers, but are now completely discarded by the more progressive designers.

Wheels. As probably the oldest principle in mechanical engineering, and certainly applied to vehicle construction centuries upon centuries before Christ, if the testimony of Egyptian hieroglyphics and the excavations of archeologists are any criterion, it would seem that the vehicle wheel should have developed very close to finality, not only because of its simplicity but also because of the time it has had to develop. Yet the activities of inventors more diligent than well informed are still directed to the devising of all manner of spring wheels and other freak constructions in the mistaken hope of thus doing away with the necessity of pneumatic tires.

Wood Wheels. Wood wheels, of the artillery type, are by far the most used on automobiles. The difference between this type of wheel and that generally employed in horse vehicles is that the common type of carriage and wagon wheel has the spokes staggered in the hub, whereas, in the artillery wheel, the spokes are bolted between two hub flanges, without staggering. The latter construction is found preferable for wheels with pneumatic tires, and the "dishing," on which so much stress is often laid by wheelwrights, becomes of little importance with the combination of workmanlike construction, small diameters, and the use of pneumatic tires.

Wire Wheels. Wire wheels, which have the spokes in tension instead of in compression, as in all other types, are the lightest, strongest, and the most elastic that can be made. Abundantly tested in the development of the bicycle, and thereafter applied to the first automobiles, wire wheels were subsequently discarded because of their appearance, rather than because of any sound engineering reason. The fact that they are somewhat more difficult to clean than wood wheels, however, may also have had some influence in forcing their disuse.

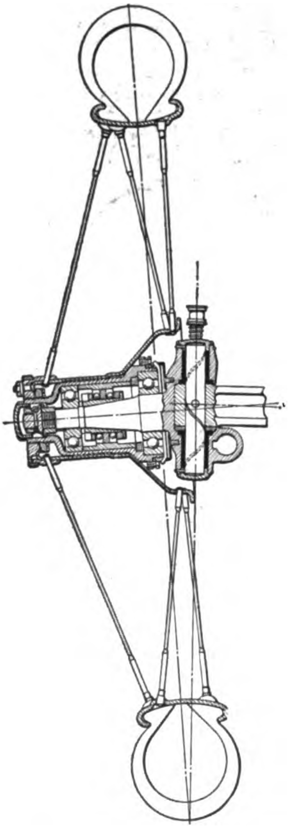

Fig. 11. Triple-Spoke Wire Wheel

Latterly there are signs that the wire wheel is coming back, and particularly in England and on the Continent, where manufacturers find greater difficulty in securing good second-growth hickory than in the United States, and where the advantages of the various types of "demountable" wheels—quickly removable from the thimble hubs upon which they are locked—are more appreciated, it is rapidly regaining its former place in popular favor.

A typical wire wheel showing the development of the triple spoke to strengthen the wheel and to take care of side strains, is illustrated in Fig. 11.

Disk Wheels. In Fig. 12 is shown an interesting example of disk wheel, built up of two pressed steel plates that are fastened together at the rim and at the hub. This wheel construction, besides being the easiest of all to clean and keep clean, affords as much strength as can be had with any other type, with less weight than with wood wheels, and with but slightly more than with wire wheels. The disk wheel is also the cheapest to manufacture, so there are many good reasons for supposing that it may possibly dispute with the wire wheel the question of ultimate supremacy.

Brakes. Important both as an engineering problem and because of their relation to safety, the brakes of automobiles have been the subject of much study and experiment.

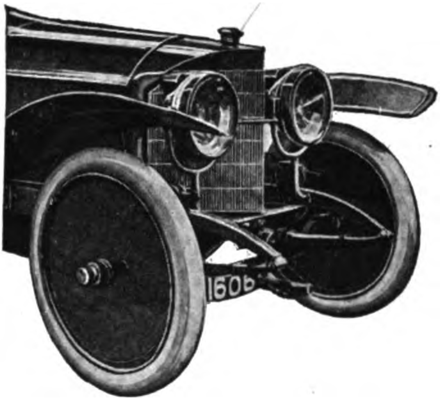

Fig. 12. Steel Disk Wheels of Mercedes Car

Expanding and Constricting Brakes. These are the common type, usually acting on drums bolted directly to the driving wheels. In the expanding type of brake the construction involves shoes contained in the drum, capable of being forced out by simple mechanism into contact with the inside of the drum rim. In the constricting type the brake is applied by a band that draws tight around the drum.

Transmission Brakes. Brakes acting upon propeller shafts, countershafts, or elsewhere in the transmission of an automobile, possess the advantage that, acting on parts that revolve at higher speeds than the wheel speeds, their action is proportionately more effective. An objection is that they may tend to cause a racking back and forth against the slight lost motion in the driving elements, as the car is alternately propelled and braked.

The arrangement illustrated in Fig. 13, in which the transmission brake is accessibly placed behind the rear axle, on a prolongation of the propeller shaft, is a construction that is coming rapidly into vogue on cars with worm-driven rear axles, the nature of the worm drive being such that it readily allows prolongation of the propeller shaft through the axle.

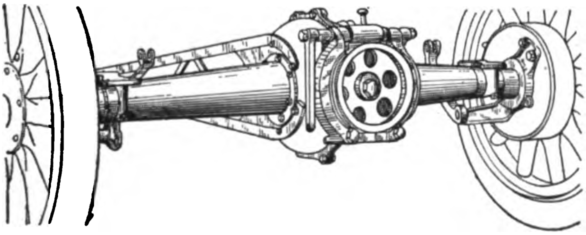

Fig. 13. Example of Transmission Brake, Back of Axle

Brake Facings. A great variety of materials are used for the wearing surface of brakes. There are the plain metal-to-metal constructions, as of cast-iron shoes against steel drums, of copper bands around steel drums, and there are the various organic facings, of one kind and another of beltings and other materials riveted to the brake shoes or bands. The best among the beltings are those of asbestos with a mesh of copper wire, since these can not be destroyed by overheating. Very effective, but subject to destruction by charring from prolonged application, are the fabric facings.

Miscellaneous Braking Devices. Under this heading are to be considered the various means of retarding a car by causing it to propel the engine by making it drive a geared-up air fan revolving under the body. Such schemes of braking are of some advantage in making long coasts in mountain country, such prolonged descents being seriously destructive of ordinary brakes unless a water drip is provided to minimize the heating and the consequent wear.

Brake Control. Automobile brakes are variously operated by hand levers and foot pedals, the usual arrangement being that of a foot pedal to the right of the clutch and accelerator pedals, with an "emergency" brake lever at the right, in close proximity to the change-speed gear lever.

Tires. Probably the greatest invention and the most important element in the automobile is the pneumatic tire, without which the motor-driven road vehicle, as we know it today, would be practically impossible.

Pneumatic Tires. The function of the pneumatic tire is almost as widely misunderstood as are its merits and its care. The really fundamental function of the pneumatic tire is its adaptation to the irregularity of the road surface, and not, as most persons suppose, a cushioning of the load by the provision of a spring action.

Conversely, the shortcoming of the steel or other hard tire is not its inelasticity but its lack of deformability. The consequence is that as a hard tire rolls along any surface of other than perfect smoothness, it must either climb over, crush, or force down all of the minute inequalities it encounters. Thus on a gravel road a steel tire expends energy in crushing gravel, in pressing small pebbles into the hard surface beneath them, and in every other way but in contributing to the efficient forward movement of the vehicle.

A pneumatic tire, on the other hand, by virtue of its deformable surface yields to every inequality, wasting energy neither in crushing pebbles nor in lifting the machine, and thus it establishes a sort of floating compromise between all the high and low spots in the road, thereby affording the substantial equivalent of an ideally perfect surface to begin with. The perfect elasticity of the confined air, which quite incidentally does afford a considerable spring action, is of high importance simply as a means of causing the tire instantly to recover its normal shape as it leaves the road that has momentarily deformed it.

From the foregoing it will be understood how mistaken are all projects, in the way of spring wheels and the like, which are based upon the supposition that the function of the pneumatic tire is that of a spring, when as a matter of fact its service as a spring is only incidental to its more fundamental functions.

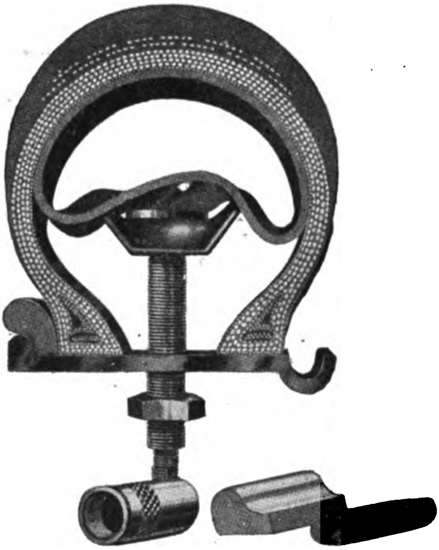

Fig. 14. Goodyear Universal Q. D. Tire and Rim

The size of tires is a point of more importance than is generally understood. The proper measure of tire cost being cost per mile, the fact that a larger wheel diameter requires fewer revolutions for a given distance traveled means not only that the larger-diameter wheel strikes holes and inequalities less abruptly, but also means that the tire makes that many less complete road contacts in going a given distance, thus reducing its exposure to wear, heating, etc.

Large tire sections are as important as liberal diameters, because with a small tire section, unless the tire is inflated to an unduly high pressure, it proves totally incapable of carrying the load, whereas with a tire sufficiently large to carry the load without undue deformation, even at a more moderate pressure, the working stresses are vastly lower.

To secure the maximum of tire service, amateur repairing by the roadside should be absolutely eliminated. The best way of eliminating it is the use of demountable rims or wheels, or quick-detachable rims, whereby the ready replacement of tubes and casings is facilitated, and the temptation to run on damaged tires is done away with.

Typical pneumatic tires and rims, of approved and standard forms, are illustrated in Figs. 14, 15, and 16.

Cushion Tires. Solid rubber tires without fabric or air in them are rather more durable at low speeds than pneumatic tires, and on the good surfaces of city streets, under cars of low speed, they possess in addition to their durability a reliability and immunity from punctures that render them preferable for certain classes of commercial and electric vehicle service.

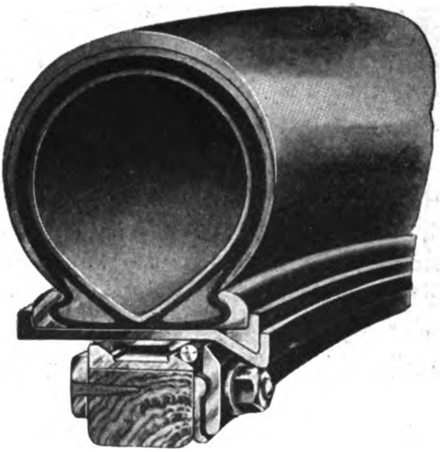

Fig. 15. Stoddard-Dayton Demountable Tire Equipment

Steering Gears. No more serious accident can befall an automobile than for the driver to lose control over its direction of travel. For this reason the design and construction of a steering gear is a subject of the greatest importance.

Wheel Steering. Steering by a hand wheel, instead of by a lever, has become almost universal within the last few years of automobile development, the only innovation in this period being the growing tendency in the United States, and in other countries where vehicles pass to the right, to place the driver and the steering wheel at the left, that he may better observe passing vehicles.

Lever Steering. Except in inside-driven electric automobiles lever steering is now practically obsolete, chiefly because it does not provide sufficient control over an automobile moving at high speed.

Irreversibility. This is an important consideration in the design of a steering gear, its object being to prevent the transmission of road shocks from the wheels to the hand of the operator, in such a way that they will quickly cause fatigue and perhaps cause the control to be jerked away from the driver for a long enough period to cause trouble. As commonly designed, automobile steering gears are so made that the steering wheel operates through a worm-and-sector, or a screw-and-nut, in such a manner that the movement can be transmitted only in one direction.

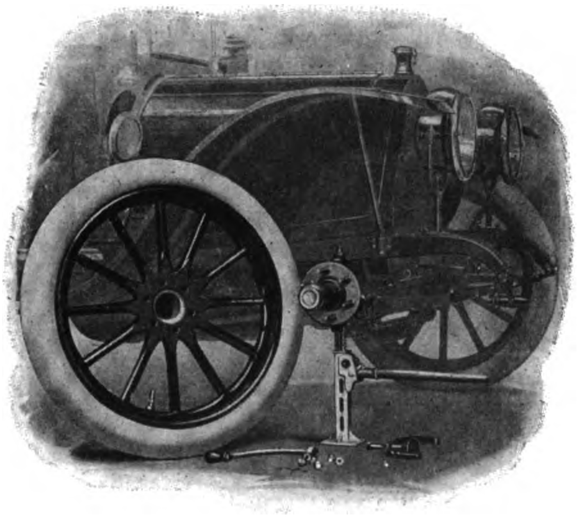

Fig. 16. Rambler Detachable Wheel
Thos. B. Jeffrey Company, Milwaukee, Wisconsin

TRANSMISSION ELEMENTS

Of quite as great importance as the development of power at the motor is its effective and efficient transmission to the driving wheels. Because of certain inherent shortcomings of the gasoline motor—its lack of flexibility, its inability to pull at low speeds, etc. —the problem of power transmission is no simple one, and has taken much solving to bring it to its present state of perfection.

Clutches. The fact that a gasoline engine is not self-starting, and that it is so inflexible that to propel a car at varying speeds requires the ratio between engine revolution and wheel revolution to be changed by the intervention of gearing, renders necessary a clutch for disconnecting the transmission from the motor during starting and gear shifting.

Cone Clutches. Consisting of a simple leather-faced cone let into a seat machined in the flywheel, this type of clutch was the first successfully applied to automobiles of modern type, and it still remains the one favored by many manufacturers and users.

Multiple-Disk Clutches. Because of a greater durability, due largely to the ability to enclose them in oil-containing housings, multiple-disk clutches have in many cars supplanted the cone clutch. In its simplest form a multiple-disk clutch consists of a pack of ring-like adjacent elements, every alternate one of which is connected by lugs first to the driven and then to the driving member. Obviously, with this arrangement, by letting the whole pack of disks be loose no transmission of power can take place, but when the disks are compressed together by springs the friction of their adjacent surfaces will cause one set to drive the other.

Miscellaneous Clutches. Clutches of various expanding and contracting types, similar to expanding and contracting brakes, are favored by a few designers of high standing.

Change-Speed Gears. The use of gearing for positively varying the ratio between engine revolutions and wheel revolutions has so far proved superior to all other methods.

Sliding Gears. Though long decried by technical critics as "brutal engineering," sliding gears have vindicated the foresight of their originators by becoming the standard present type, to the almost total extinction of all alternative devices. Made of good materials and stepped down in ratios not too abruptly varying, they can be made to afford reliability and durability both truly remarkable, considering the small proportions generally used and the large amounts of power often transmitted.

Planetary Gears. Though still used in only a very few cars, the planetary gear can be designed so as to render good service, and a point that particularly commends it is the certainty that in the hands of even the most incapable or careless operator it is not possible to strip the gear teeth, which are always in mesh, and the different combinations of which are brought easily into engagement by the gradual application of brake bands.

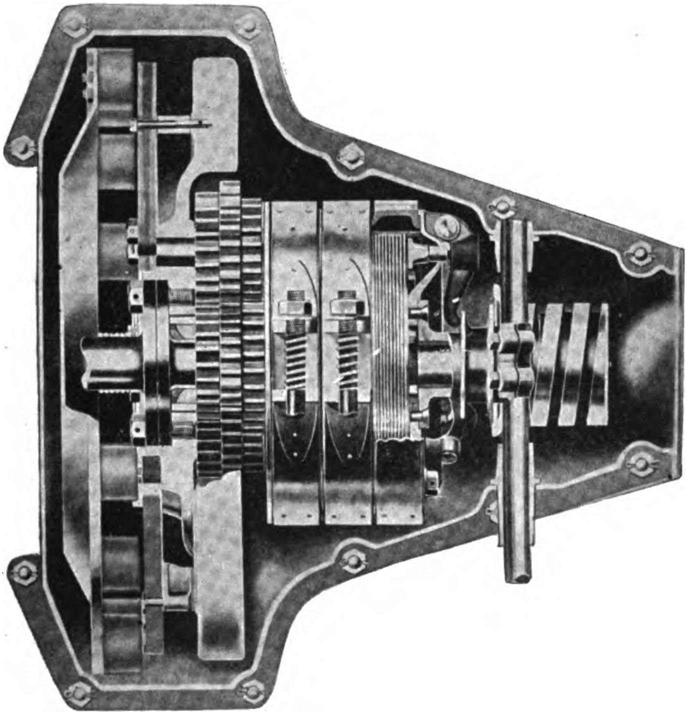

Fig. 17. Ford Planetary Gear Transmission
Ford Motor Company, Detroit, Michigan

The type of planetary gear used on the Ford automobiles, of which many thousands are in use, is illustrated in Fig. 17. The product of long experience in designing this type of a gear, and with the further experience back of it that has been accumulated in the use of perhaps a hundred thousand cars, it is safe to say that this gear represents the most advanced practice in the design and construction of its particular type.

Individual-Clutch Gears. Though never extensively used, the class of gear in which the pairs of gear wheels are always in mesh, but are brought into action only by individual clutches—either of the gradually-applied brake type or of positively-engaging jaw type—has some features of conspicuous merit.

A French gear of this type is illustrated in Fig. 18, in which the driving shaft is *A*, the driven shaft *B*, and the countershaft *C*.

Fastened to shaft *A* are the gears *D, E, F, G*, and *H*, which are in mesh at all times with the gears *I, J, K, L*, and *M* on the countershaft, *I* being in mesh with *D* through the intermediate gear *N* shown in the end section and giving the reverse rotation. The gears on the countershaft *C*, with the exception of *O*, are engaged to it only by the longitudinal movement of the spline *P*, the gear *O* being keyed to *C*, as shown in the upper section. Gear *Q* is integral with shaft *B*. Change of speed is accomplished by shifting spline *P* to the proper point, *EJ* giving the first speed, *FK* the second, *GL* the third, *HM* the fourth, and *DI* the reverse.

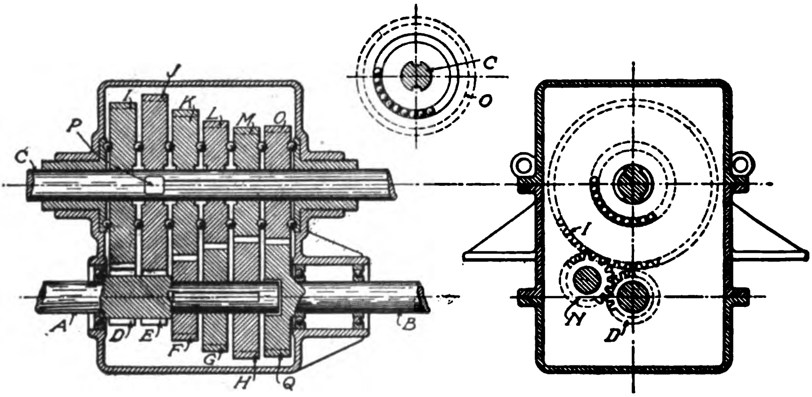

Fig. 18. Crepet Individual-Clutch Transmission

Another individual-clutch gear of much interest is that illustrated in Fig. 19, in which the drives from one shaft to another are wholly by silent chains. The chains in this gearbox, which is that of the English Maudsley car, not only are of a strength impossible to secure with gears, but in addition work with a most exceptional silence. In exhaustive tests made with this type of change-speed gear on the motor omnibuses in London, it is claimed that the results secured were in every way superior to those to be had with gears.

Universal Joints. To allow for the movement of the axle, in the cases of shaft-driven cars, and to take care of slight frame distortion, affecting the alignment between gearbox and motor even in chain-driven cars, universal joints at suitable points in the shafting are a proved necessity in all automobiles of any pretense to quality or sound design.

Usually in shaft-driven cars there is a universal joint only at the forward end of the propeller shaft, or perhaps at this point and also at a point adjacent to the rear axle. The use of some sort of universal joint between clutch and gearbox is also very common.

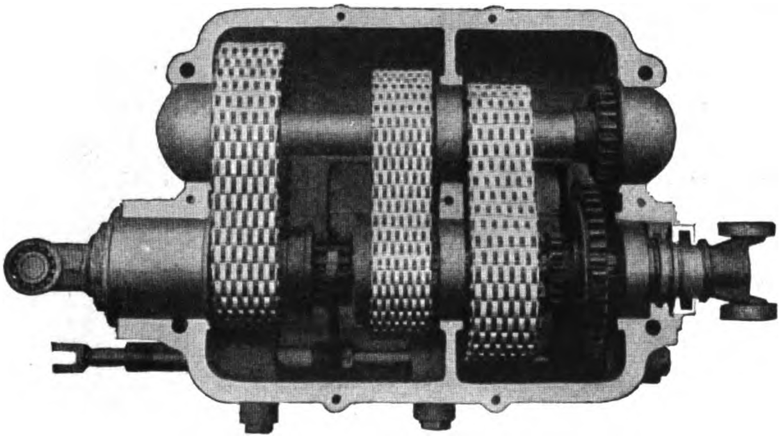

Fig. 19. Maudsley Gearset with Silent Chains

Final Drives. Possible types of final drive, from the gearbox to the rear axle and the driving wheels—or from the motor to the gearbox, in case this is mounted on the rear axle, as is not uncommon practice—are practically limited, in cars of sound design, to shaft and double-chain constructions.

Shaft Drive. In its usual form, shaft driving in an automobile involves simply a propeller shaft interposed between the rear axle and a revolving shaft in the car, above the spring action. There is further involved some provision for taking the torque of the shaft and of the axle, so that these shall maintain their proper relative positions.

It is an objection to this type of drive that the reaction of the revolving shaft tends to tilt the whole car on its springs in a direction opposite to that in which the shaft is turning. In some cars this is counteracted by the use of slightly heavier springs on one side. The advantages of the shaft drive are the complete enclosure of all working elements, with their consequent protection from dirt and assurance of their proper lubrication.

In Fig. 20 is illustrated the final drive of the Ford automobile, in which the end of the propeller shaft is shown at *A*, together with the bearings in which it revolves, the pinion by which it drives the car, the axle, the differential, and the bearings of the floating inner elements of the axle.

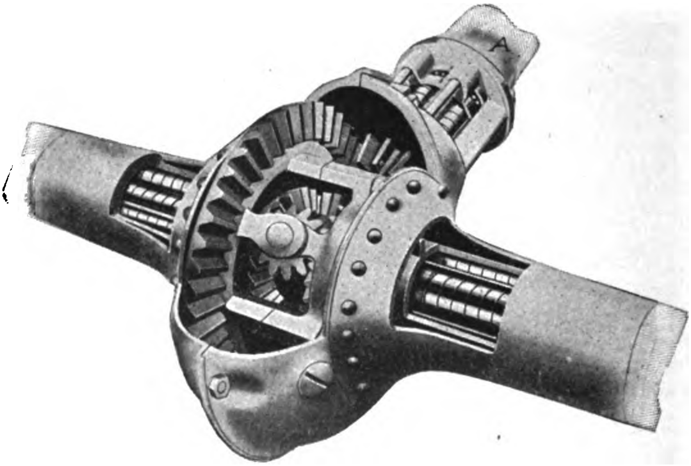

Fig. 20. Ford Final Drive, Differential, and Axles

Double-Chain Drive. The use of double chains, by which the driving wheels of an automobile are driven from a countershaft across the frame of the machine, is a practice possessed of a number of advantages. But because of the noise and quick wear with badly designed chain drives and the difficulties of completely enclosing the driving mechanism, chains are not now as popular as formerly. Nevertheless, the elimination of universal joints working through large angles and under heavy loads, the avoidance of heavy weights carried on rear axles without spring support, the lowering of the clearance by the differential housings, etc., are very real objections that the double chain avoids.

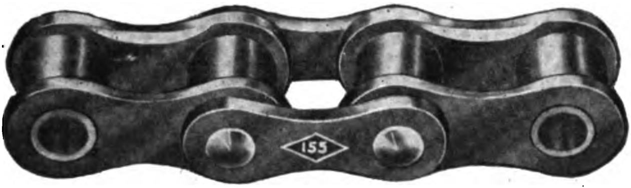

Fig. 21. Typical Roller Chain

For trucking and other heavy service, chains are still commonly in use, and it is the belief of many that better understanding of their merits, and the means of securing these merits in positive and permanent form, will result in their more general use.

A typical roller chain, of the type most used for automobile drives, is illustrated in Fig. 21.

Silent chains, of the types illustrated in Figs. 22, 23, and 24, possess certain points of superiority over roller chains and so are coming increasingly into use for cam-shaft drives, in gearboxes, etc., and there is some possibility that they will find more extensive application than at present to final drives.

The action of a silent chain is illustrated in Fig. 23, in which it is seen that as the chain links enter the sprocket teeth, the chain teeth at the same time close together and settle in the sprocket with a wedging action that causes them to be absolutely tight, but without any more binding than there is backlash.

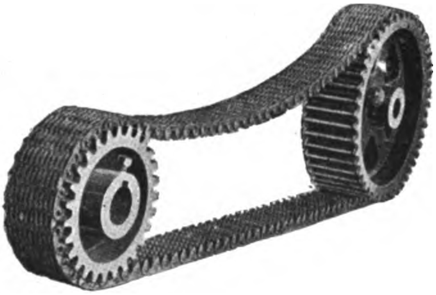

Fig. 22. Silent Chain and Sprockets

To keep silent chains from coming off sidewise from the sprockets over which they run, it is customary to make the side links of deeper section than the center links, as is illustrated in

Fig. 24. Another successful scheme is grooving the sprockets to receive a row of special center links in the chain, which are made deeper than the standard links.

Single-Chain Drive. With the rear axle built as for shaft drive, but with a sprocket wheel substituted for the usual bevel gear, it is practicable to drive an automobile by a single chain, and in the past this system of propulsion has been embodied in many automobiles. It is now not in favor, because, instead of advantages, it tends to combine the disadvantages of both the shaft and chain drives—involving the heavy axle of the one and the difficulty of protecting the mechanism, which is an objection to the other.

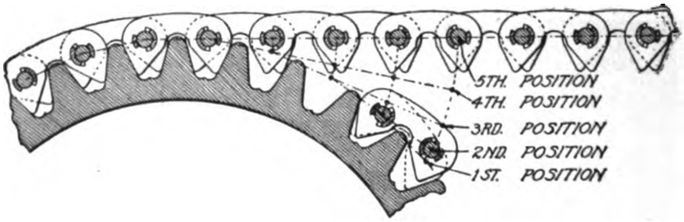

Fig. 23. Action of Silent Chain and Sprockets

In any chain drive that is subjected to intermittent loads and shocks, it is desirable to have one of the sprockets made as shown in Fig. 25, which illustrates a type of spring-cushioned sprocket recommended by one of the largest chain manufacturers in the world for the purpose of absorbing the shocks without permitting them to impose direct and heavy stresses on the chain.

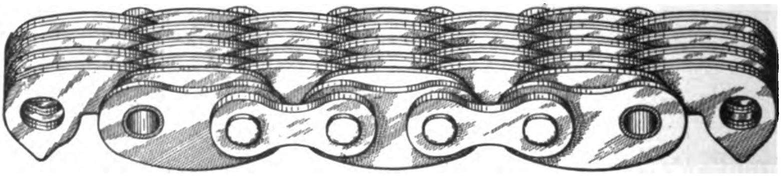

Fig. 24. Typical Silent Chain

Bevel Gears. On the axles of shaft-driven cars, and in the countershafts of chain-driven cars, it has been almost universal practice to employ bevel-gears for turning the longitudinal to a transverse drive.

Worm Gears. In the present era of high-speed automobile motors, however, there is an increasing tendency to employ carefully-designed worm gears in the final drive, because of the greater reduction they allow in the gear ratio without at the same time involving excessively large gear sizes.

Differential Gears. The need of a differential or "balance" gear, to permit the driving, while at the same time avoiding a rigid connection between the two rear wheels, will be readily appreciated when it is realized that in all but straight travel one of the rear wheels must turn faster than the other. Differential gears are the common means to permit of this, though, of course, in certain types of friction transmissions, and in electric, hydraulic, and other transmissions in which there is individual driving of the wheels by devices more or less non-positive in their character, the need for a differential is escaped.

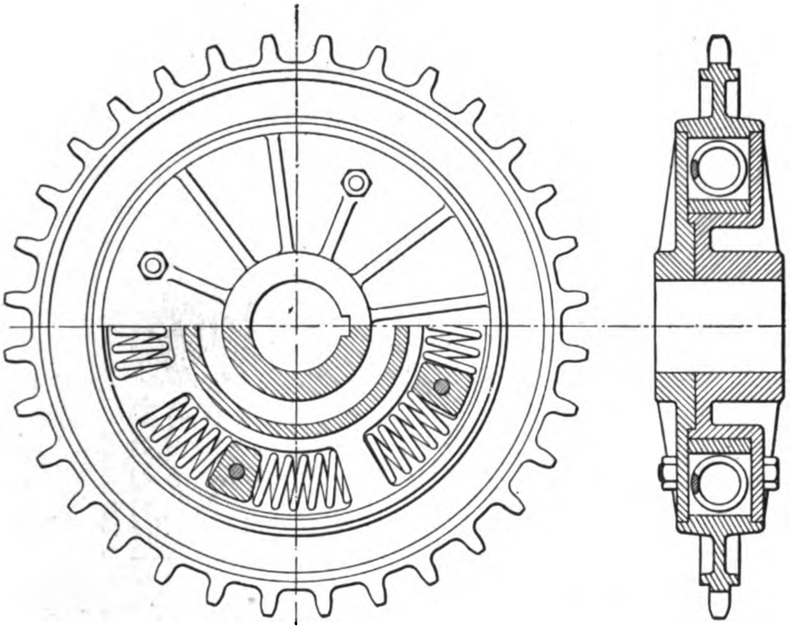

Fig. 25. Spring-Cushioned Sprocket for Intermittent Loads

A typical differential gear is illustrated in Fig. 20.

Miscellaneous Transmissions. Of the other than purely mechanical means that have been employed for transmitting the power of an automobile motor to the driving wheels, among the most successful are various types of electric, friction, hydraulic, and pneumatic transmissions.

An electric transmission, especially if the transmission system includes a storage battery for its starting and balancing effect, can be so designed as to afford very satisfactory service.

A French taxicab with a gasoline motor driving a dynamo, from which the current is taken to drive electric motors on the front wheels, is illustrated in Fig. 26. With an electric front-wheel drive of this character, or with all four wheels similarly driven by electric motors, the ability of the machine to pull itself out of bad holes, or over bad roads, is much greater than that of the ordinary motor car.

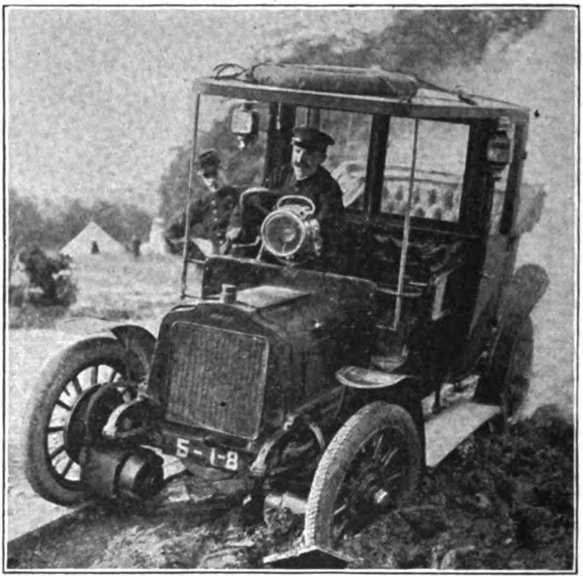

Fig. 26. Electric Front-Wheel Drive on French Taxicab
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For light vehicles, in which the power transmitted is not very great, and for service in level country, certain types of friction drives have been found quite successful. Their absolute foolproofness, rendering them perfectly immune from damage at the hands of even the most incompetent drivers, is greatly in their favor.

Among the hydraulic drives, the most successful is the Manly, a system that is fully described elsewhere herein.

The chief shortcoming of the pneumatic drives that have been developed so far is their inefficiency, the considerable amount of energy expended in heating the air as it is compressed being permanently lost unless some sort of complicated reheating device is used to warm the air again before it is employed to do the work of propulsion.

ENGINE ELEMENTS

The principles of engine design and the methods and details of engine construction are certainly in interest and importance second to none of the other factors that combine to produce the complete modern automobile.

How automobile engines operate, the reasons underlying the various details of different designs, and the relative merits of different constructions are all too little understood by the generality of those that have to do in a practical way with the new conveyance.

Cycles of Engine Operation. In all motors, of whatever sort, and of any type whatever other than those in which there is a perfectly continuous development of the power through constantly rotating elements—as in the electric motor and the steam turbine—there must be reciprocating elements that function through indefinitely-repeated series of operations. Such a series of operations is termed the cycle of the engine, as is abundantly explained elsewhere herein, so it will suffice here to call attention to some of the merits and demerits of the different cycles that are in practical use.

Two-Cycle Engines. That type of internal combustion engine in which every stroke in one direction is a power stroke affords a maximum of power impulses to any given number of engine revolutions, but because of other limitations it is not always possible to make a two-cycle engine run as fast as a four-cycle, so that in the generality of cases the number of explosions in a given period of time, or for a given vehicle speed, is no greater with a two-cycle than with a four-cycle engine.

In addition to this, most two-cycle engines are often difficult to start, apt to be wasteful of fuel, not at all flexible in the matters of speed and pulling power, and in various other respects difficult to apply to automobile service. Their greatest merit is their extreme simplicity.

Four-Cycle Engines. The four-cycle engine is the type by which nine hundred and ninety-nine out of every thousand of present automobiles are propelled. Varied through an immense number of possible forms, and with minor differences in the product of every maker, its fundamental functioning has nevertheless proved so far the most suitable for automobile propulsion.

With the succession of suction, compression, explosion, and exhaust strokes afforded by the four-cycle motor, there is secured a very positive and reliable functioning, and by the expedient of a sufficient cylinder multiplication to afford good mechanical balance and frequent power impulses, its flexibility, durability, and practical quality in every respect can be brought to very high standards in a well-designed and honestly-built motor.

At the same time, the fact that so much more attention has been paid to the four-cycle motor than to any of its possible competitors for popular favor undoubtedly accounts in some measure for its present pre-eminence, and it is an open question with many engineers as to just what virtues might or might not be realized with other constructions were they as exhaustively experimented with and exploited.

Six-Cycle Engines. This possible construction, which has already been referred to, though it sacrifices something in the way of impulse frequency, is, nevertheless, thought by some to possess an important future, as a means of practically eliminating water cooling, which at present constitutes so severe a shortcoming in and so great a subtraction from the otherwise considerable merits of accepted types of four-cycle and two-cycle motors.

Cylinder Multiplication. There seems no reasonable limit to the extent to which cylinder multiplication can be carried, in the effort to improve the mechanical balance and to even the torque of gasoline motors, but established practice has, nevertheless, settled upon four-cylinder vertical engines as those most suitable for the propulsion of the average automobile—this being the least number of vertical cylinders with which mechanical and explosion balance can be secured.

The use of six cylinders, with the crank throws 120 degrees apart, and the explosions occurring once for every 120 degrees of crank-shaft rotation, affords a smoother running motor than the four-cylinder.

Still better than the "six" from every standpoint but that of cost, which has prevented its wider application to automobiles, is the V-shaped, eight-cylinder motor, of the type illustrated in Fig. 27, which gives a good view of a well-known French automobile motor. In this motor there is used an ordinary four-cylinder crank shaft—which is much cheaper to manufacture than a six-cylinder crank shaft—and the two rows of cylinders, each practically constituting a separate four-cylinder engine, are made to work upon the common crank shaft at 90 degrees apart.

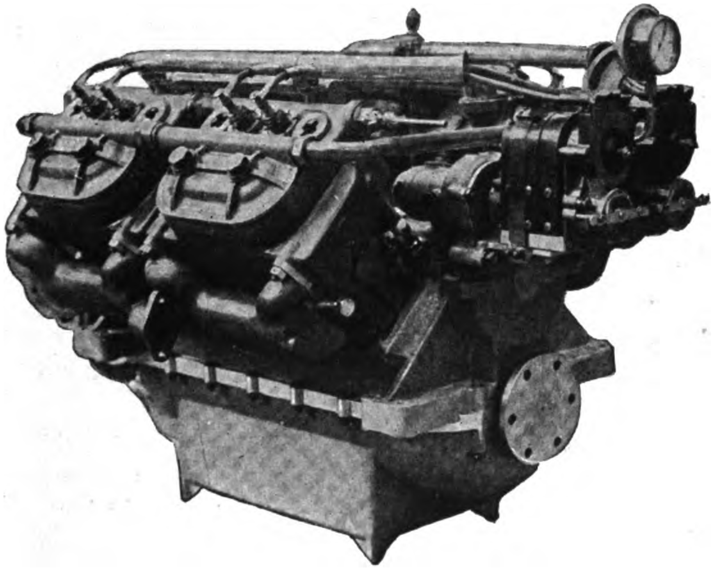

Fig. 27. Eight-Cylinder De Dion Automobile Motor
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For aviation use eight-cylinder, V-shaped motors have been very common, and it is believed by many that their further development in this field will result in their more extensive application to the automobile.

A very unique type of multicylinder motor, which in a highly practical form is distinctly a development of very recent years, is the revolving motor of the general type illustrated in Fig. 28. So far there is only one automobile to which the revolving motor has been successfully applied, this being a five-cylinder machine that has been built by an American concern for a number of years past.

Though the shortcomings of the revolving motor are serious and include such difficulties as those inseparable from the great space it occupies, the difficulty of muffling it, the impossibility of adjusting it while it is running, etc., nevertheless, its merits are extraordinary.

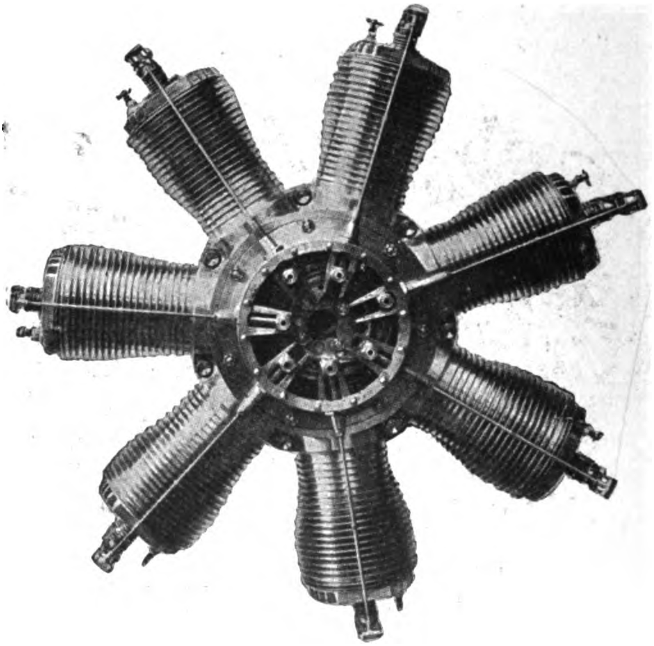

Fig. 28. Peugeot-Rossel Seven-Cylinder Revolving Aviation Motor
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Important among these, as is obvious, is the fact that it permits three, five, seven, or more cylinders to deliver their power to a very short, light, single-throw crank shaft. Then there is the fact that the large revolving mass totally does away with any necessity for a flywheel. A third point of merit, which is the practical elimination of reciprocating parts, with their consequent vibration, is less apparent. It will be understood, however, by reference to Fig. 29, which is a model showing the usual arrangement employed in multicylinder revolving motors. In this illustration, the connecting rod from the piston of cylinder A terminates in the large disk on the crank shaft, to which the rods from the other pistons are linked. The first consequence is that this "master rod" prevents the center disk B from revolving on the crank pin, except as the whole engine revolves with it.

Now it is obvious that, as the cylinders revolve around the crank shaft, they can have no reciprocating motion. But since the pistons are attached by links of fixed length—the connecting rods—to the master-rod disk on the crank pin, it also follows that, as the cylinder revolves, the pistons must revolve too, with the crank pin as the center of the circle around which they travel. The result is that there are two sets of rotating parts, one the cylinders, and the other the pistons, revolving in two circles eccentric to each other, so that instead of any actual there is only a relative reciprocation, as the two classes of working elements, cylinders and pistons, approach and recede from each other as they move around their respective circles of travel.

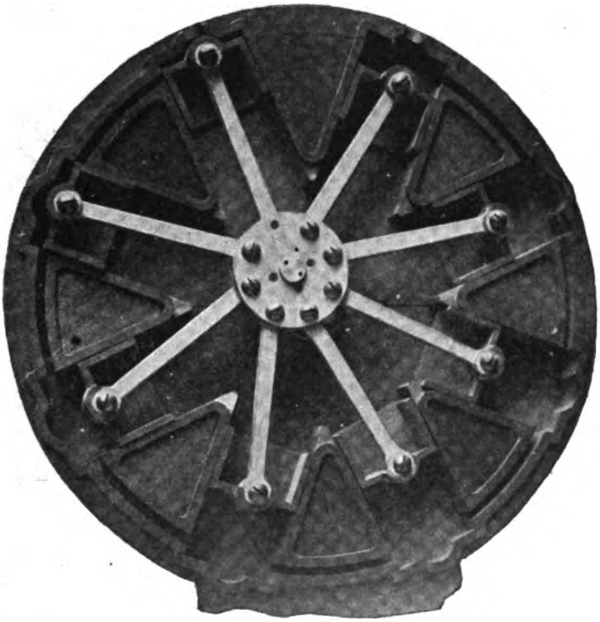

Fig. 29. Connecting-Rod Arrangement of Revolving Motor
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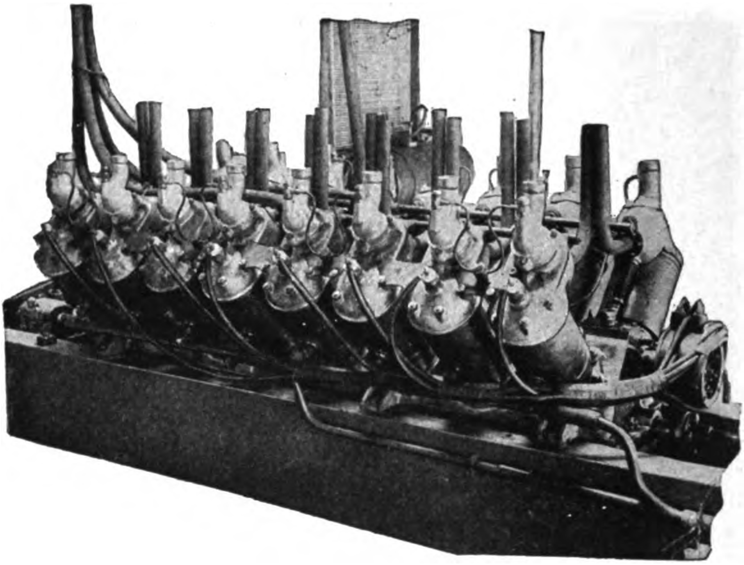

Fig. 30. Sixteen-Cylinder Antoinette Aviation Motor

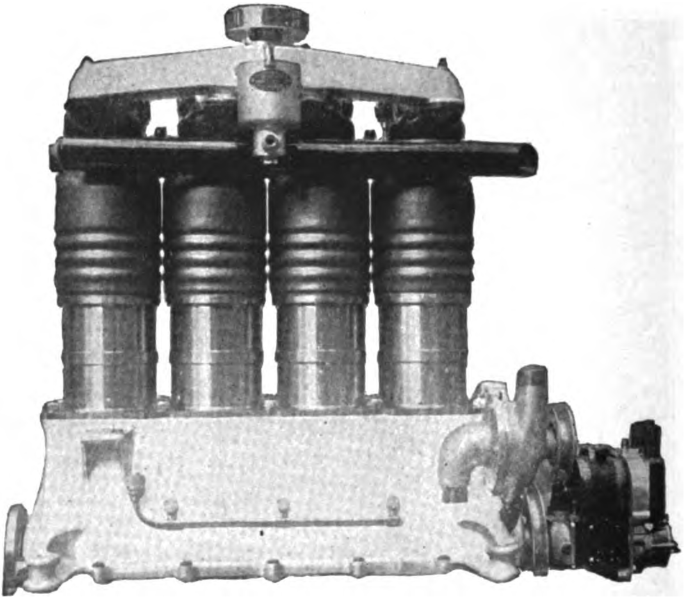

Fig. 31. Panhard Motor with Individually-Cast Cylinders
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The immunity from vibration resulting from this condition is almost perfect in a well-designed revolving motor.

An extreme example of cylinder multiplication is shown in the sixteen-cylinder, 100-horse-power, V-shaped motor illustrated in Fig. 30. This is an Antoinette motor, of a type that has scored important successes in motorboat racing and in aviation. To some extent the same motors have been applied in automobiles.

Cylinders. Gasoline-engine cylinders are variously made of cast iron, cast and forged steel, aluminum alloys, and other materials.

For durability, and the ability to withstand high temperatures without warping, nothing has been found superior to cast iron, though the lightness of steel and aluminum alloys has commended them for aviation use, and, in some cases, for racing automobiles.

Cast Separately. Early and still common practice, in the building of multicylinder gasoline motors, was the casting of cylinders separately, it being by this policy easier to secure sound castings, simpler to machine and finish them, and less troublesome to disassemble parts of the motor without disturbing the rest.

In Fig. 31 is shown an example of a motor with cylinders individually cast, this being a Panhard aviation motor in which each cylinder is machined outside and in, and the water jackets, of sheet copper, applied afterwards.

Cast Together. The great advantage of having the several cylinders of one motor cast together—*en bloc,* as the French term it—is that the alignment and spacing of the different cylinders is thus rendered absolute and permanent, regardless of any differences in adjustment that may otherwise occur in assembling.

Another advantage is that the water connections, exhaust and intake manifolds, etc., are rendered simpler both in their form and the number of their points of attachments.

In some advanced motor designs the passages for the incoming mixture and the exhaust gases, and in one case even the carbureter itself, are all incorporated in the main casting.

A very neat example of a four-cylinder motor in which the cylinders are cast together, with built-on water jackets of sheet metal, is that illustrated in Figs. 32 and 33, which show an aviation motor made by a well-known French automobile builder.

Another example of simple construction is that illustrated in

Fig. 34, which depicts one of the latest Ford motors, in which cylinder, upper half of the crank case, and the gearbox are all cast in one piece. The lower half of the crank case and gearbox are similarly constituted of another simple casting, while a third casting is used for the heads of the cylinders and the water connection.

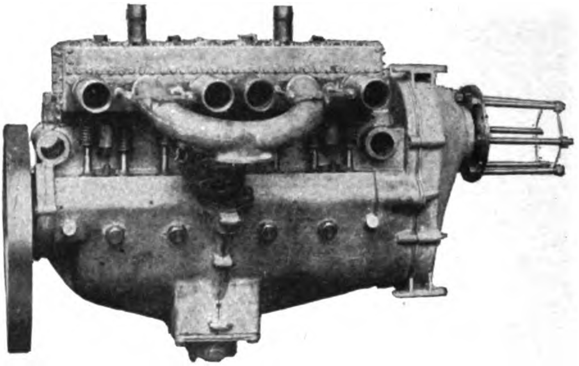

Fig. 32. Lemale Aviation Motor with Cylinders Cast "En Bloc," (Right Side)

Piston. The pistons of automobile motors have long been made of cast iron, with the piston pin held in bosses on the piston walls. For all ordinary service this construction, well carried out, serves every purpose, but with the development of very high-speed motors, with piston speeds twice and three times as high as past practice has

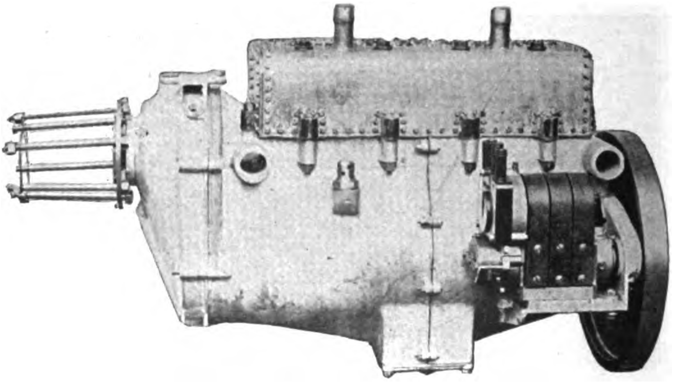

Fig. 33. Lemale Aviation Motor (Left Side)
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sanctioned, there is a growing tendency to substitute steel for cast iron in this important reciprocating element.

Particularly in aviation motors has this been the case, the pistons of one well-known revolving motor, for example, being machined to the thinnest possible sections out of a high-grade alloy steel. In this motor the connecting rods are hinged to the head of the piston instead of to the walls, which thus can be made much thinner than otherwise would be necessary. This practice has been followed to a slight extent by some automobile manufacturers, and there are now a few stock cars of established quality that are provided with pressed-steel pistons.

Cast iron for piston rings, long used to the exclusion of everything else, is in slight degree yielding its pre-eminence for this purpose also. This is because it has been found, in aviation motors with steel cylinders, that bronze affords greater durability and smoother running against the steel cylinder wall, for which reason bronze rings—with steel or cast-iron springs, or "bull rings," behind them—have been found most advantageous.

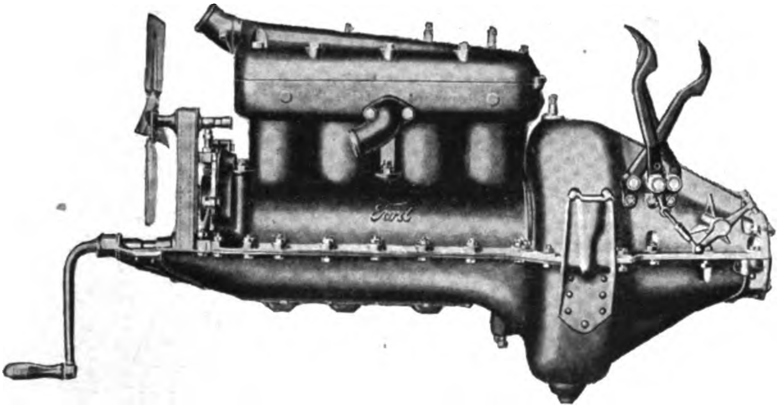

Fig. 34. Ford Engine with Cylinders, Crank Case, and Gearbox in Two Castings
Ford Motor Car Company, Detroit, Michigan

Connecting Rods. Established practice in connecting-rod design is almost all in favor of the common **H**-section rod, usually with two bolts to attach the cap. In some cases four bolts are used, since with four bolts a flaw or crack in one is less likely to cause damage than is the case when only two are used. The old scheme of hinging the cap at one side is now practically obsolete, having been discarded because of the fact that it made accurate adjustment of the bearing surfaces almost impossible.

Tubular rods, in place of the H-section, are giving good service in several of the long-stroke foreign motors, and it is difficult to see why this form is not superior to that in common use. The question of cost, however, is a consideration, since it is necessary to bore the hole through the inside of the rod, whereas a forged rod of H-section requires no machining except at the end.

One advantage of the tubular rod, in addition to its superiority for withstanding the compression load to which a rod is chiefly subject, is that it can be used as a pipe to convey oil from the big end to the piston-pin bearing.

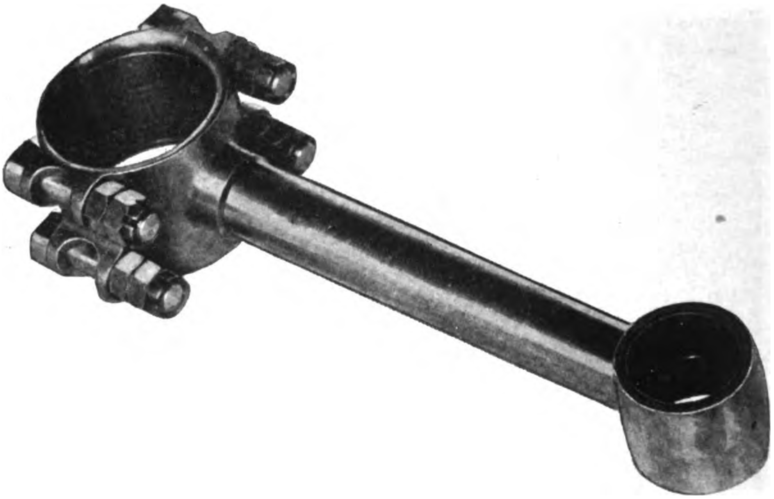

Fig. 35. Connecting Rod Machined out of One Piece of Alloy Steel, with Four Cap Bolts

In Fig. 35 is illustrated an example of a very light-weight, high-quality, aviation-motor connecting rod, machined out of the solid bar of alloy steel, and provided with four bolts in the cap.

Crank Shafts. The greatest variations in automobile crankshaft design, aside from those permitted or made necessary by differences in the quality of material, are due to the conditions involved in the different combinations of cylinders that can be utilized. Thus the number of crank throws as well as their position varies with the type of motor.

The duty of a crank shaft is of so severe a character, involving the practical equivalent of thousands upon thousands of heavy blows, that for any but very heavy, slow-running motors the crank shaft should be made of nothing but the finest alloy steels obtainable.

Valve Mechanisms. In the valves and valve mechanisms of modern gasoline engines there have been and are impending more interesting changes than seem in prospect in any other portion of the mechanism of the modern automobile. Particularly is this the case with reference to the present tendency to discard the poppet valve with its many objectionable features.

Poppet Valves. Though the very first internal-combustion engines ever made were operated with slide valves, the poppet valve was introduced very early in the history of this art. and has reigned supreme in practically all types of gas and gasoline engines.

The chief advantage of the poppet valve is its capacity for continuing operative at excessively high temperatures, but since the cooling of engines has progressed to the status of high reliability this advantage is of less importance than formerly. And the disadvantages of poppet valves—the small openings that they afford, the noisy and hammering action they involve, their tendency to leak and in other ways give out, and the necessity for frequently regrinding them—are objections so serious that it is not to be wondered at that the prospect of their elimination is so widely welcomed.

About the only recent improvements that have been made in poppet valves are in the quality of material used in them—the best valves now being those with cast-iron and nickel heads, which offer a maximum resistance to warping from the heat to which they are subjected, and with carbon-steel stems, which are superior in their wearing qualities. The use of casings to enclose the valve stems, springs, and push rods, so as to keep these elements from exposure to dirt while at the same time silencing in large degree the noise they otherwise make, is also becoming usual.

A characteristic example of present methods of casing in poppet valves is shown in Fig. 36, which is an example of a Fiat marine motor, with the valve stem pit in the side of the motor covered by a readily-removable aluminum plate.

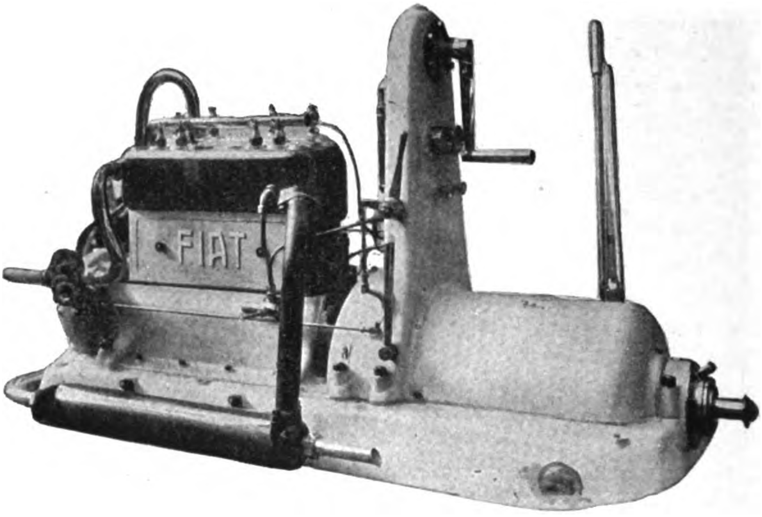

Fig. 36. Fiat Marine Motor with Encased Valve Action
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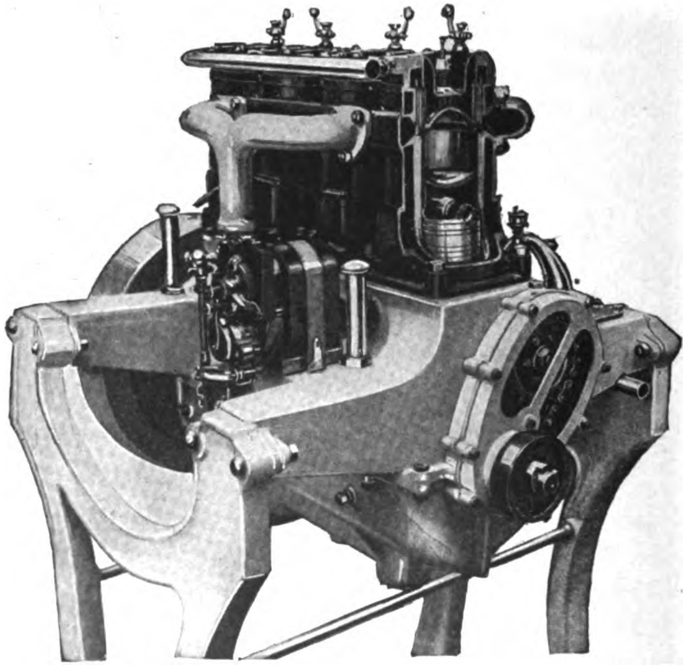

Fig. 37. Minerva-Knight Motor with Sliding Sleeve **Valves**
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Sleeve Valves. This type of valve, while not at all new, has only within the past couple of years come into considerable prominence, chiefly as a result of the truly remarkable performances of the Knight motor, which is equipped with the most advanced examples of this type of valve.

Contrary to past opinion, it has been conclusively demonstrated that sleeve valves do not in any perceptible degree increase the tendency of a motor to overheat, nor do they wear at any very measurable rate. They afford, moreover, in the best constructions, a much higher thermal and mechanical efficiency than it is possible to secure from the average poppet-valve motor, this improvement being due to the better-shaped combustion chamber that can be used, and the greater areas of valve opening, which facilitate the ingress and egress of the charges.

Another advantage in favor of the sleeve valve is that its timing is permanent and unchangeable, and does not alter materially with wear. Not the least of the merits of the sleeve valve is found in the fact that it lends itself to positive operation by eccentric mechanisms, which are in every way greatly superior to the non-positive cam mechanisms universally used to actuate poppet valves.

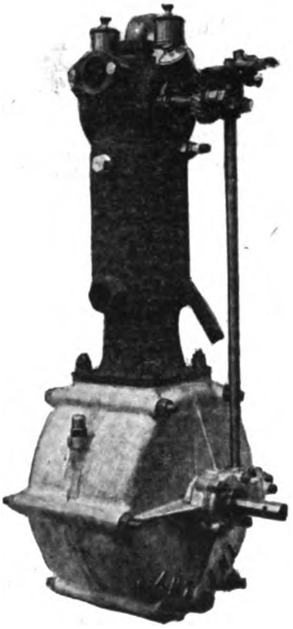

Fig. 38. Single-Cylinder, Rotating-Valve Anzani Engine
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A very perfect example of the latest type of Knight motor is that illustrated in Fig. 37, which shows this engine as it is built by the Minerva Company, of Belgium.

Sliding Valves. Sliding valves of other than the sleeve type, embracing a considerable variety of piston valves and valves similar to those employed in steam engines, have not found as much favor with designers of automobile engines as have other types herein referred to.

One exception is the successful use of a "split-ring" valve, sliding up and down in the cylinder head just above the piston, which has found successful application in a few motors recently built by the Renault Company, of France.

Rotating Valves. A rotating valve of characteristic type is that employed in the single-cylinder engine illustrated in Fig. 38, which is an experimental motor designed by Anzani, famous as the designer of several European automobile motors, and of the aviation motor with which Bleriot effected the first flight across the English Channel. This motor is provided with a plain rotating sleeve in the cylinder head, turned at a constant speed by skew gears.

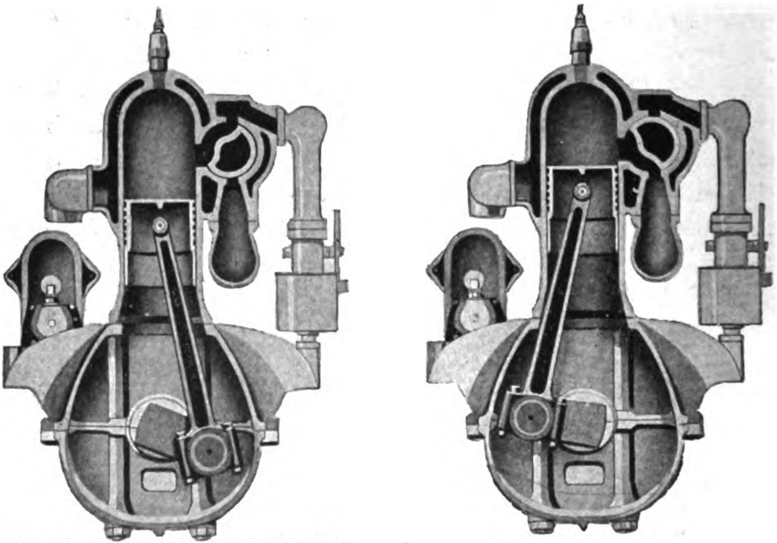

Fig. 39. Sections of Darracq Rotating Valve Motor Showing Intake Position (left) and Exhaust Position (right)

Other rotating valves that have proved successful are the Darracq valve, illustrated in Figs. 39 and 40, and various rotating inlet valves used on the crank cases of two-cycle motors, such as that illustrated in Figs. 41 and 42.

The Darracq rotating valve is a particularly clever example of sound designing, and exhaustive tests have proved it thoroughly successful and reliable.

Much of its merit undoubtedly inheres in the fact that the port through which it communicates with the cylinder is closed by the piston at the top of the stroke, so that at the moment of explosion the valve is shielded from the highest temperatures that occur within the cylinder.

Halftime Shafts. For the actuation of the valve mechanism of any four-cycle motor, it is necessary to have a shaft (or in the case of rotary valves, to run the valve itself as a shaft), turning at one half the speed of the crank shaft through a two-to-one gear ratio.

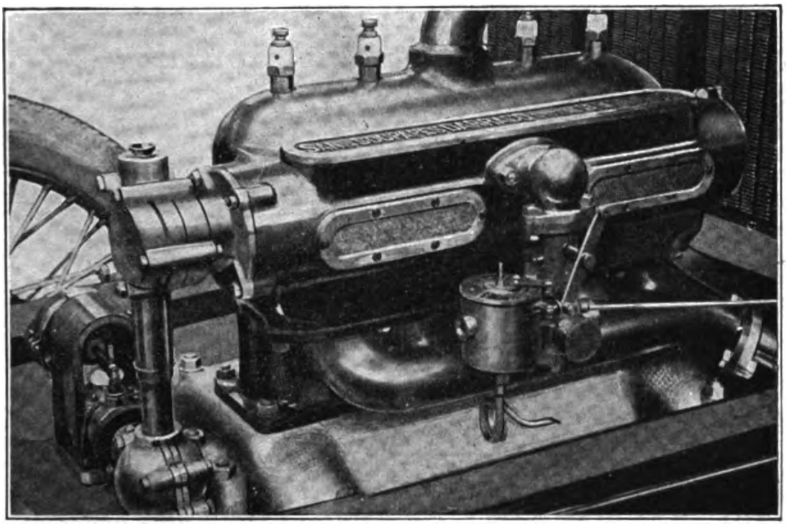

Fig. 40. Complete Darracq Rotating Valve Motor
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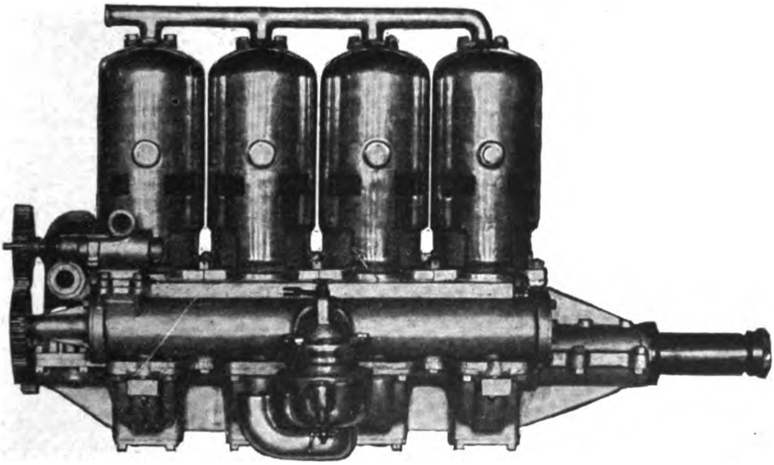

Fig. 41. Roberts Two-Cycle Motor with Rotating Crank-Case Valve
E. W. Roberts, Sandusky, Ohio

Ordinarily the halftime shaft is the cam shaft, but in motors of the Knight type it is, of course, an eccentric shaft. Cam shafts particularly call for good workmanship and high-grade materials, as well as sound design, since the constant pounding of the valve stems or push rods on the cams is a prolific source of trouble if anything but the soundest of sound construction be employed.

The most important recent innovation in this detail of automobile mechanism is the driving of halftime shafts by silent chains, in place of the long-used gearing, of spur and helical type. By this improvement the noise of the gears is eliminated.

Carburetion. While improvements are constantly making in the details of carbureters, and much important knowledge has accumulated concerning the properties of explosive mixtures and the best methods of their positive compounding, carbureters of today present few fundamental deviations from those of years past.

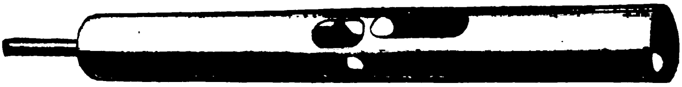

Fig. 42. Rotating Inlet Valve of Roberts Two-Cycle Motor

New Fuels. For some years past there has been under way a subtle though not less radical change in the character of the fuel—the gasoline—used for the propulsion of automobiles. The small production and the increasing demand have combined to render almost unpurchasable, except at high prices and then from large dealers, the lighter and more volatile gasolines of some years ago. In the place of them there have been quietly introduced much heavier petroleum distillates, which evaporate less readily—though they are actually of higher value in terms of power units. This condition has compelled several changes in the carbureter problem.

In addition to the foregoing, in some parts of the world there have been serious efforts made to utilize in automobile motors alcohol and benzene (not benzine), which with proper provision for their carburetion constitute excellent fuels.

The most important of the changes dictated by this development in the fuel situation is the now general practice of heating the float chambers of carbureters, either by water from the circulating system or by exhaust gases. An alternative scheme is the drawing of the air for the carbureter from a point adjacent to the exhaust piping, so that this air is sufficiently warmed to take up readily the gasoline necessary to constitute with it a proper explosive mixture.

Fuel Injection. Systems of fuel feeding by direct injection of minute quantities of the combustible liquid into the cylinders, or into the intake piping, have been advocated or experimented with for many years, and have found very successful application in stationary and flight engineering, though as yet not one of these systems has successfully competed with the carbureter in automobile service, where the conditions of power variation are such that fuel injection has not seemed readily applicable.

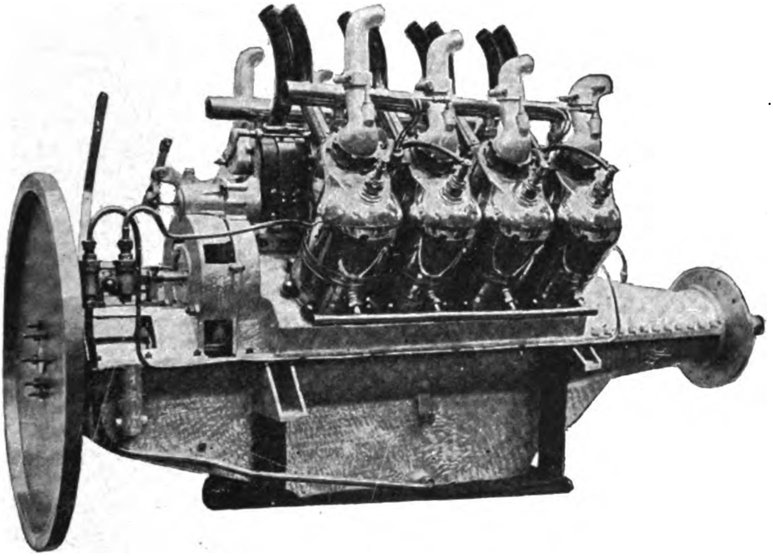

Fig. 43. Eight-Cylinder Antoinette Aviation Motor with Fuel Injection
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Nevertheless, there are many engineers who adhere to the view that sooner or later fuel injection will supplant present systems of carburetion, and progress made recently with aviation motors of fuel-injection types may seem in some measure to justify this view.

One of the most successful fuel-injection motors is the Antoinette, illustrated in Figs. 30 and 43. In the latter illustration, the fuel pump is shown at A. By this pump the fuel is injected directly through small copper tubing into the intake pipes on the cylinders.

As has been previously mentioned, these motors have proved very successful in both aeroplane and motorboat applications, but the fact that in both of these vehicles constant running at full power rather than variation of speed is the requisite, largely discounts inferences that may be drawn concerning the general applicability of such motors to automobile uses.

WATER COOLING

Though nearly all successful automobile motors, as well as most other internal-combustion engines, are water-cooled, there is so much obvious fault to be found with this system of securing a result —involving first the generation of heat and then its waste by a complicated refrigerating system, instead of its utilization by converting more of the heat units into useful work—that it is scarcely credible that water cooling can persist indefinitely.

Water Jacketing. The first essential in water cooling a motor is to provide the cylinders with water jackets, through which the cooling water is circulated in contact with the outsides of the walls within which the heat is liberated.

Water jackets are of two types, integral and built-up. The latter system of construction, though adding to complication and conducive to leakage, permits of lighter construction, besides diminishing the likelihood of hidden flaws in the cylinder castings, which with cored jackets are not likely to reveal themselves until they cause breakdown, perhaps after the engine has been long in use.

In Figs. 44 and 45 are shown two characteristic examples of built-on water jackets, the jackets of both of these motors being made of sheet metal, formed around the cylinders, and attached to flanges left on the cylinder casting by closely-placed small screws.

The type of attached copper water jacket illustrated in Fig. 31, however, is generally considered superior to that shown in Figs. 44 and 45, because in the former case there are avoided the screws, the jacket being simply a hollow shell forced over the cylinders and held by ring-like clamps at the two ends. This greatly reduces the liability to leakage.

An important advantage of applied jackets of the type just described is their freedom to yield in case the water freezes in them.

Thus is eliminated the danger of cracked cylinders, which not infrequently result from exposure to cold weather in ordinary automobile motors having jackets integral with the cylinder.

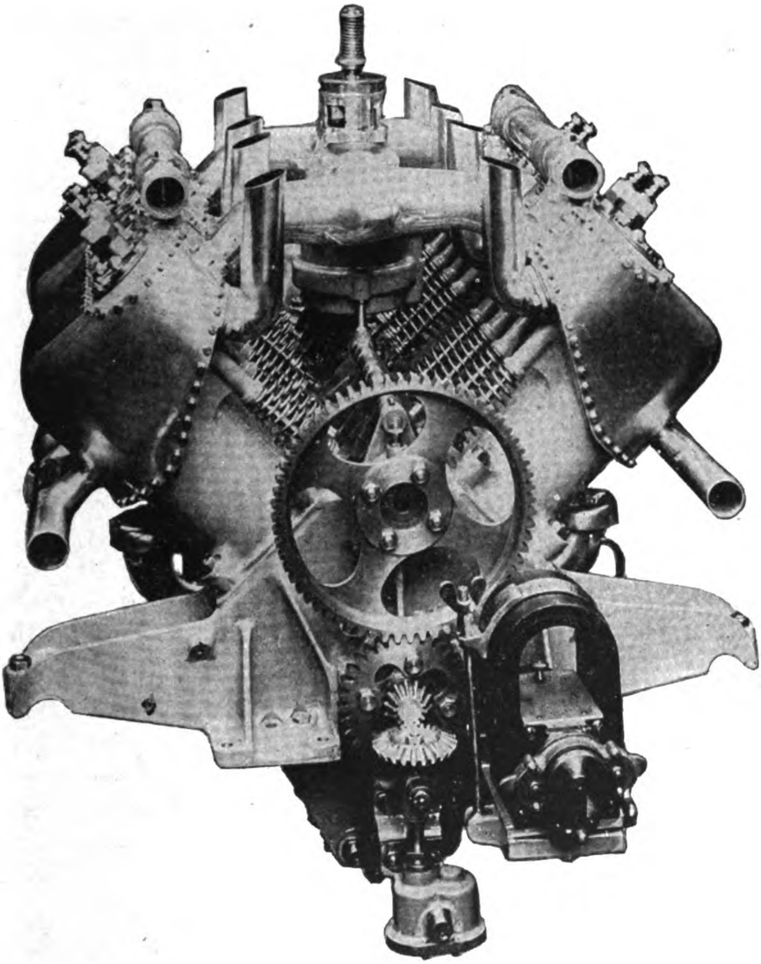

Fig. 44. Wolseley Aviation Motor with Attached Water Jackets
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A particularly neat method of water jacketing, which has been applied with some success abroad, consists in the electro-deposition of copper jackets on the cylinders, through the use of wax molds to produce the desired forms. Jackets thus applied, though somewhat expensive, are said to be practically indestructible and completely proof against leakage.

With integral jackets the usual system is to form the jackets by cores in the founding, so that there are no openings in the jackets except those for removing the core sand and wires, and for connecting the pipes of the circulating system. In many of the best examples of motor design, however, the core openings are left very large but with plane faces, and are closed by screwed-on or clamped-on plates, thus making the construction practically a compromise between the completely integral and the completely built-on jackets.

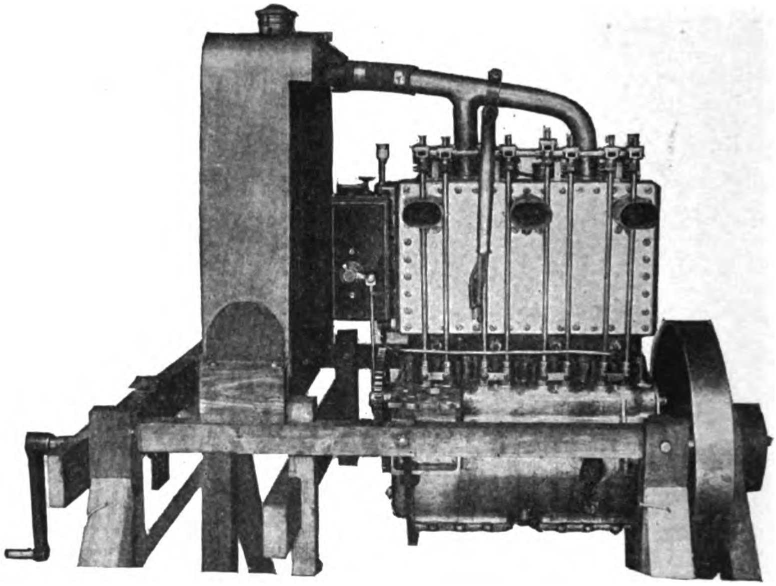

Fig. 45. Gregoire Aviation Motor with Attached Water Jackets
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Radiators and Piping. It has often been pointed out that all cooling of automobile engines is in reality air cooling, the water-cooled motor being simply one in which the heat units to be disposed of are conveyed from the cylinders by the circulating water, to be then dissipated in the air that passes through the radiator, instead of directly lost in air passing over thin flanges cast on the cylinders. A water-cooling system therefore constitutes a sort of indirect air cooling. This being the case, the chief justification for water cooling consists in the margin it allows for much greater cooling areas in contact with air than it is possible to provide by mere extensions of the cylinder surfaces themselves.

The total cooling area of the radiators employed in automobiles will range all the way from ten to ninety square feet, the latter being not unusual in the best type of honeycomb radiators, with hexagonal openings and very thin water spaces.

The smaller areas are found in the cheaper types of radiators, built up of straight, round, or flat tubes, and provided with fins to increase the area exposed to the air. Radiators of these types, unless very large, are often inadequate to cool a motor when it is laboring under continued heavy usage, as in pulling on the low gear through deep sand or mud, or up long, heavy grades. Under such conditions a motor that may have run for months without any cooling trouble whatever in level country, will often boil all of the water out of the cooling system within a few minutes.

The piping of automobile cooling systems is in a great many cars made too small to afford free circulation, and this mistake in design, common in the earlier days of automobile engineering, is one that can not be too carefully avoided.

In the experience of most automobile designers, the most satisfactory method of connecting up the piping of a circulating system is found in the use of ordinary steam hose, clamped around the ends of the pipe by small metal straps.

Considered an improvement over this by a few designers is the use of steam hose for practically the entire piping system, doing away with metal piping altogether except as this is needed close up to radiator and water jackets for the attachment of the hose.

Circulation. An unobstructed and vigorous circulation of the water in a cooling system is a great factor in reducing the size of radiator required, and in preventing overheating and boiling away of the water.

Pumps. The usual method of circulating the cooling water is to use one type or another of small pump, driven by suitable gearing from the engine itself.

Gear pumps are often used for this purpose, because of their extreme simplicity, but it is difficult to make them large enough to handle as great volumes of water as most designers now regard as desirable.

The consequence is that the centrifugal pump is now the type most preferred. In their best forms centrifugal pumps consist of simple multi-bladed "impellers," revolving with close clearances in a housing.

One advantage of the centrifugal pump is that if any small objects, such as a stick or pebble, should by any chance get into the circulating system—though strainers always should be provided to prevent this contingency—no serious harm is likely to result, whereas with a gear pump breakage is almost certain to ensue.

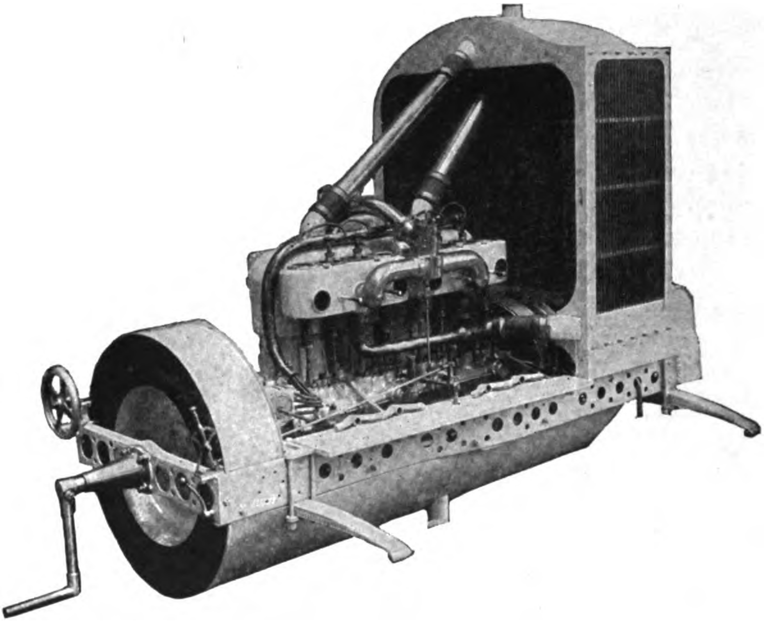

Fig. 46. Renault Motor with Thermosiphon Circulation
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Chiefly in motorboat motors, of the two-cycle types, reciprocating plunger pumps are used to circulate the cooling water. The volume of water handled by pumps of this type, of dimensions that can be conveniently employed, is not very large, however, and it is only the fact that the water is not re-used and is, therefore, cooler, and of a consequent greater effectiveness, that makes possible the use of plunger pumps in motorboats.

Thermosiphon. Circulation of the cooling water by the thermosiphon action, due to the heated water in the jackets rising and the cooled water in the radiator descending, is the practice of an increasing number of designers, and has been demonstrated to be very effective with liberal jacket spaces and large-diameter piping.

The pioneer and still the most prominent exponent of thermosiphon cooling is the Renault Company, of France. A typical Renault motor-and-radiator combination, with thermosiphon circulation, is illustrated in Fig. 46.

Fans. In the earlier days of automobile designing it was deemed sufficient to secure circulation of air through the radiators by the movement of the car alone. This was soon found inadequate, however, since often at the times when most cooling was needed, as in hill climbing or hard pulling on the level, the car would be moving at its lowest speed on low gear, with the result that the air draft through the radiator was not sufficient to cool the water.

This condition was remedied by the use of a fan behind the radiator, driven by a belt or gearing from the motor, so as to draw a constant draft through the radiator in proportion to the speed of the engine rather than of the car.

Nowadays practically all automobile power plants are provided with fans, the only exceptions being a few very small motors, in which the difficulty of cooling is not so great as with the higher powers.

In some cases, instead of a separate fan, fan blades are placed on the flywheel, and so made to induce a draft through the bonnet that covers the engine, thus avoiding the necessity for the addition to the moving parts involved in the usual fan system. Such a flywheel fan is used in the engine illustrated in Fig. 46.

Anti-Freezing Solutions. In using automobiles in very cold climates in the winter months there is great danger of the water in the cooling system freezing when the car is standing still, or even with the motor running slowly if the temperature be very low. The result of such freezing is almost certain injury to the cylinders, through cracking of the water jackets, as well as the probability of bursting out radiator seams with consequent leakage.

To avoid these difficulties it is not uncommon to use, instead of pure water, one kind or another of anti-freezing solution, usually compounded by the mixture of some chemical with water, to lower its freezing point. Thus, glycerine or alcohol mixed with water will keep it from freezing at all ordinary winter temperatures. Glycerine is somewhat objected to because of its sticky, gummy nature, and also because of its deleterious effects upon the rubber hose of the piping system. Alcohol will, if not replenished from time to time, evaporate out of the water and thus permit it to freeze, or, if mixed in too great a quantity, it may introduce a fire risk otherwise avoidable.

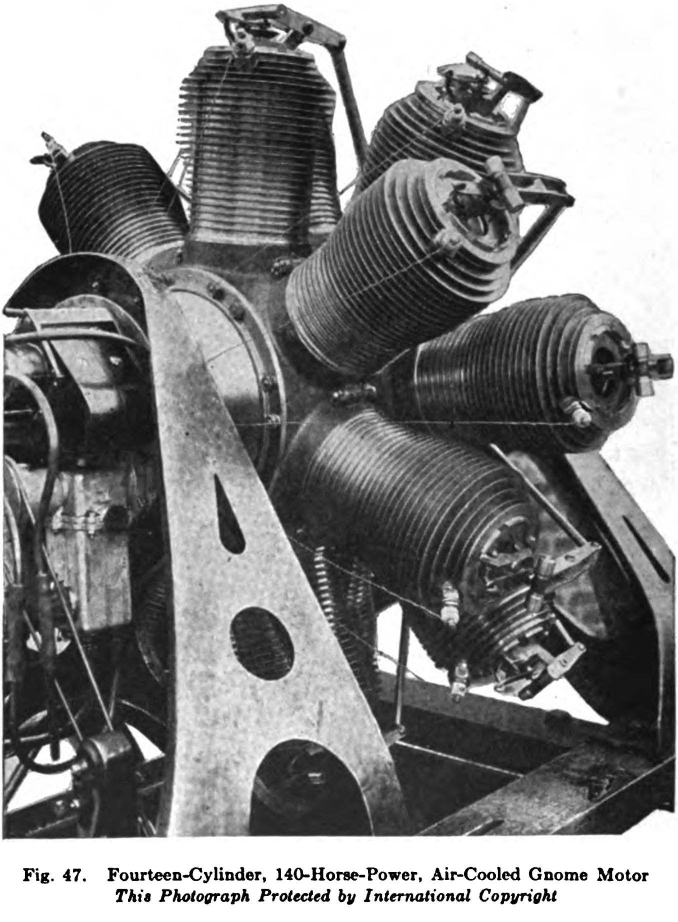

Fig. 47. Fourteen-Cylinder, 140-Horse-Power, Air-Cooled Gnome Motor
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A much favored anti-freezing solution consists of calcium chloride dissolved in water, in quantity proportioned to the temperatures that it is desired to guard against.

All anti-freezing solutions are more or less objectionable in that they are more likely than pure water to corrode and clog up the circulating system, and there is no doubt but what the elimination of the necessity for them, by the substitution of air cooling for water cooling, will mark a great advance in automobile development.

AIR COOLING

Though successfully employed in one or two automobiles, and remarkably developed in some of its applications to aviation motors, air cooling is not considered by most engineers to be successfully applicable to the average automobile. That it will become more practical in the future, however, is the opinion of many.

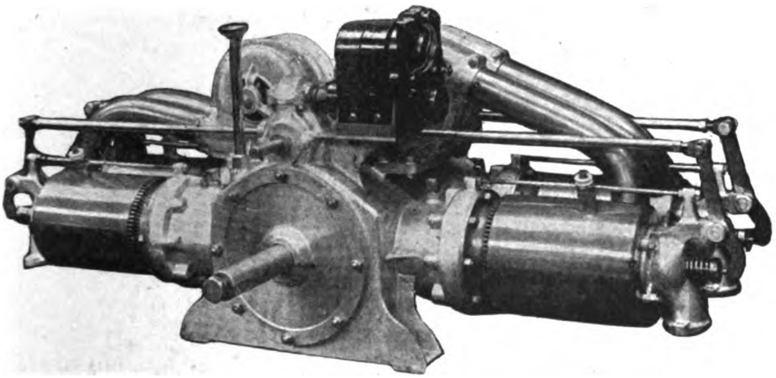

Fig. 48. Miesse Aviation Motor with Air Jackets and Blower
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Flanges and Fins. The usual method of air cooling, successfully employed in aviation and motorcycle motors and in a few automobiles, is to provide the cylinders with fins or flanges for increasing the area of the surface, supplementing this with means for blowing large volumes of air over the surfaces thus provided.

A beautiful example of successful air cooling is that illustrated in Fig. 47, which shows one of the 120-horse-power, fourteen-cylinder, Gnome revolving aviation motors, which are perfectly cooled by air in spite of the fact that they deliver an immense power for their weight, and are capable of delivering this power without breakdown or failure for long periods of time.

Air Jackets. Several of the most practical examples of air-cooled motors in aviation constructions are ones in which, in addition to the flanges or fins on the cylinders, these are surrounded by air jackets to concentrate the drafts of air that effect the cooling.

One construction of this kind is that illustrated in Fig. 48, which shows a well-known make of four-cylinder aviation motor in which the cylinders are provided with longitudinal ribs, enclosed in air jackets, through which blasts of air are constantly forced by the centrifugal blowers shown at *AA*.

Another example of an air-cooled motor with air jackets over the cylinders is that illustrated in Fig. 49, in which the air is supplied by blowers on the ends of the shaft.

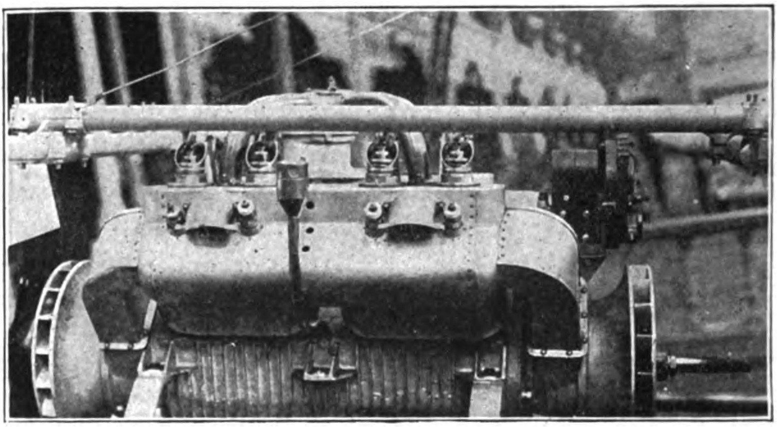

Fig. 49. Pipe Air-Cooled Aviation Motor
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Blowers and Fans. The most successful air cooling has been accomplished, as has already been explaind, by types of blowers capable of inducing much more vigorous air currents than are commonly drawn through the radiators of water-cooled automobiles by the types of fans in common use in power plants of that character.

In addition to such constructions as that illustrated in Fig. 49, and the conventional type of centrifugal blower utilized in the engine illustrated in Fig. 48, a very successful example of highly specialized and highly effective construction is that shown in Fig. 50, which depicts an eight-cylinder, V-shaped Renault aviation motor, cooled by volumes of air greatly in excess of those employed in any other air-cooled engines yet built. These liberal volumes of air are, moreover, produced with a minimum waste of power, through the use of a scientifically-designed and very efficient centrifugal blower.

Engines of this make, in eight-cylinder models, have captured important records in aviation.

Internal Cooling and Scavenging. Perhaps more promising as a road to final and universal use of air cooling, are the systems of pumping air through the interiors instead of blowing it over the exteriors of the cylinders. Such internal cooling—in addition to directing the maximum cooling effect where it is most needed, on the oil-coated surfaces that are exposed to the heat of combustion—has the further advantage that it may be made to scavenge out all residual exhaust gases, which, besides helping to accumulate heat, also act so detrimentally upon the functioning of ordinary motors. This is a direct result of the admixture of retained exhaust gases with incoming fresh charges.

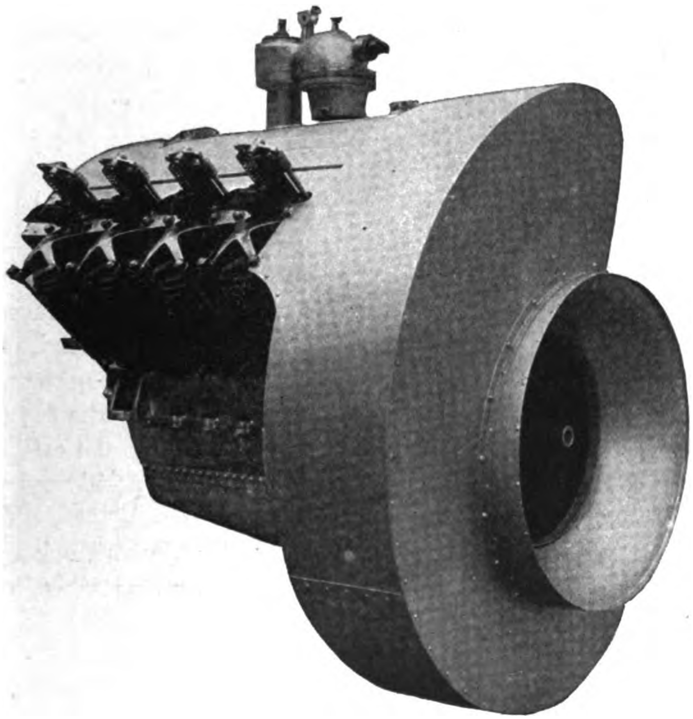

Fig. 50. Blower-Cooled Renault Aviation Motor
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It is generally considered by those best qualified to judge that a large proportion of the cooling effect secured in the Gnome motors is due to the passage of the incoming charges first through the crank case and thence through the piston. Since the pistons are the first element to give trouble when a motor overheats, there can be no doubt that conducting the cool fresh mixture through the piston must concentrate a cooling effect of great benefit at this point.

In addition to this, in the Gnome motors, as also in the Franklin air-cooled automobile motors, the compressions employed are much lower than in standard automobile practice, and the cylinders are normally required to deliver much less power than is commonly secured from cylinders of the same dimensions, thus showing that one road to air cooling is to be found in not taxing the cylinders to the utmost of their power capacity.

Methods of internal cooling and scavenging that appear of definite promise are those proposed in various recent schemes for pumping air first into the crank case—either by using the under side of the piston as a pump, as in common two-cycle construction, or by applying special pumps to the crank case for this particular purpose—the air thus pumped being then transferred into the cylinders by means of by-passes, with the result that it exerts a positive cooling effect inside of the cylinder.

By elaborating this construction in conjunction with six-cycle systems of functioning, so that there are two complete strokes in the cycle devoted to the specific purpose of pumping scavenging air through the cylinders, some remarkably successful results have been secured in experimental investigations of which the writer has knowledge.

LUBRICATION

A first condition of reliability and continued service in any type of motor is the positive and unfailing lubrication of its bearings.

In automobiles it is particularly important that the lubrication be of a positive and foolproof character, requiring a minimum of attention to assure its certain operativeness.

Pressure Feeding. A very successful and one of the best types of lubrication systems is that in which the oil is fed under pressure to the different bearings.

Reservoir Pressure. With an oil reservoir in which a constant air pressure is maintained above the oil, there is the reasonable certainty that the lubricating fluid will constantly pass out through the piping that leads to the different bearings, and lubrication systems based upon this principle, with minor modifications, have been extensively used in automobiles, one system being shown in Fig. 51.

An objection to lubricating systems of this type is that, in case there are several leads to different bearings, one of them may become obstructed without anything to indicate this condition or to overcome it, until the bearing involved becomes overheated and ruined. This is because, if one lead becomes obstructed, the oil can still continue to feed out through the others, thus relieving the pressure in apparently the normal manner, and so concealing a serious derangement.

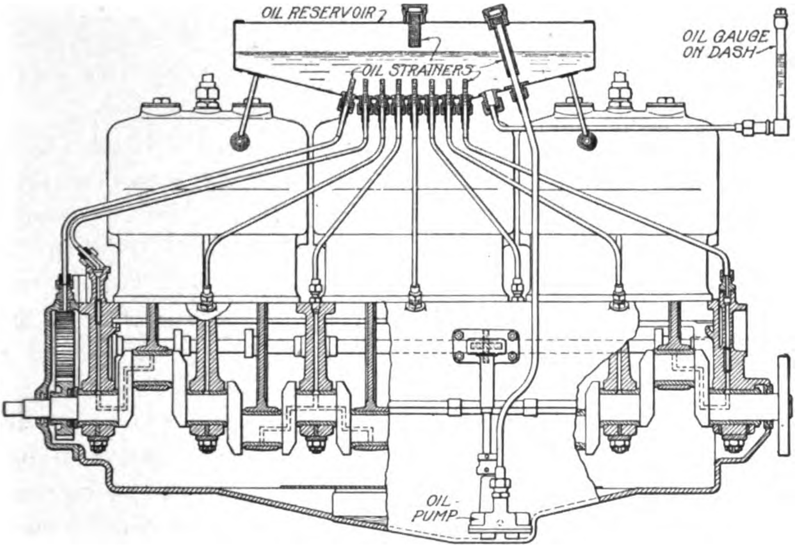

Fig. 51. Pierce Multi-Feed Oiler
Pierce-Arrow Motor Car Company, Buffalo, New York

Individual Pumps. To avoid the objection just stated, the expedient of feeding the oil by individual pumps, independently-driven and capable of individual adjustment, so as to feed any desired amount of oil to any particular bearing regardless of the amount that may be fed to any other bearing, has been widely applied. In such a system, should obstruction of any one of the leads occur, such obstruction is practically certain to be forced out by the action of the pump, which in all lubricating systems of established type is made capable of working against enormous pressure.

Gravity Feeding. Feeding of oil by gravity to one or more bearings is a method that has been employed with some success, but it is now encountered only in rare instances in automobile power plants.

Splash Lubrication. The feeding of oil to bearing surfaces by the simple expedient of enclosing a quantity of it in a reservoir in which the working parts are also contained, is a successful and widely-used scheme in automobile motor construction.

One of the simplest types of splash lubrication, applicable only to shaft bearings, is the use of ring or chain oilers of the general type illustrated in Fig. 52, in which *B* is the shaft and *A* is a ring loosely encircling it and dipping in an oil pit formed in the shaft bearing. As the shaft revolves, the ring *A* naturally works around it and its lower portion as constantly dips in the reservoir of oil, so it must feed this oil up to the top of the shaft, whence it distributes itself throughout the length of the bearing. A deeper and narrower oil reservoir can be used in the place of the ring *A* if there be substituted a short length of endless chain.

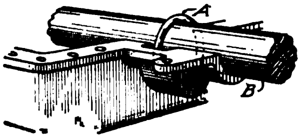

Fig. 52. Typical Ring Oiler

In splash lubrication as applied to gasoline motors, a common and successful system is that illustrated in Fig. 53. In this the crank case, which is shown without the cylinders, is partitioned by a shelf into an upper and lower half. In the lower portion there is maintained the constant level of oil at *A*, from which sump or storage pit the oil is constantly drawn by the small gear pump at *C* and thence sent forth through a small pipe to the sight-feed-oiler indicator *D*, passing from this to a horizontal pipe in the crank case provided with a row of small holes *E*. From these it spouts out in small streams into the shallow splash pits on the shelf at *B*.

In these pits the oil automatically maintains itself at a constant level because an excess is constantly pumped and the excess disposed of by overflow back to the sump at *A* as fast as the oil reaches the tops of the partitions between the different pits.

To effect the lubrication, the lower ends of the connecting rods dip at the bottom of each revolution into their respective pits, whence they splash the oil violently over all the cylinder walls and bearings.

Oil and Grease Cups. For the lubrication of bearings that are not constantly working, or which do not carry very heavy load, oil and grease cups are very serviceable. Even to the cylinders and crank shafts of automobile engines oil cups of large size find some application, and if these are made of the type in which a constant and regular drip of oil can be provided, with fairly definite control as to quantity, they can be made to serve their purpose much better than might be expected.

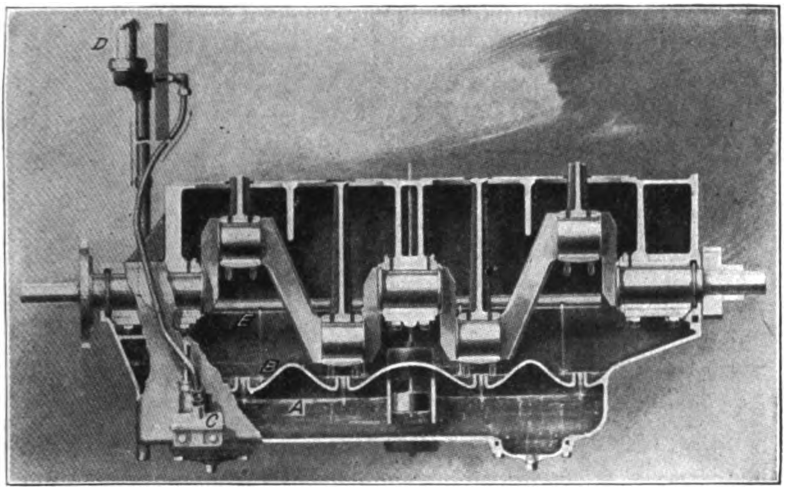

Fig. 53. Sump System of Splash Lubrication
Haynes Automobile Company, Kokomo, Indiana

Nevertheless, such lubrication is no longer considered as adequate and certain as automobile mechanism really demands, and the use of lubricating devices of this character is now generally confined to the application of grease cups to such elements as clutch yokes, to the eyebolts of springs, to steering pivots and the joints in steering gears, etc.

A typical oil cup of the type just referred to is illustrated in Fig. 54, in which *A* is the glass reservoir through which the quantity of oil available can be ascertained at a glance; *B* is an adjusting screw for controlling the rate of drip from the reservoir; *C* is a glass through which the flow of oil can be noted as it descends drop by drop, from the reservoir *A* to the bearing; and *D* is a lever for turning the flow on and off.

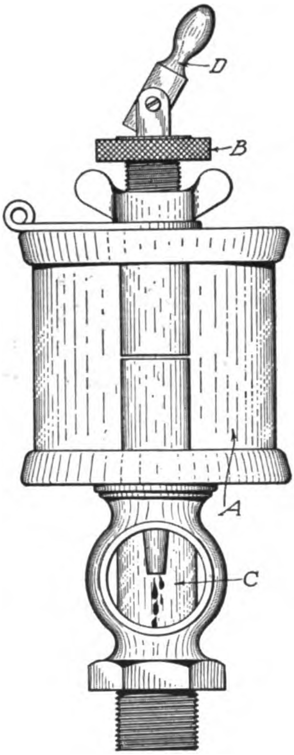

Fig. 54. Typical Oil Cup

In Fig. 55 is shown a grease cup for application to spring eyebolts. This grease cup is of the type that feeds through being occasionally screwed up a small distance as the bearing uses up the lubricant, and its positive action is rendered more certain by the use of a detent (not illustrated) that holds the cover in any position in which it may be left. The grease is contained in the entire cap *A*, which when unscrewed from the lower portion *B* is readily and conveniently filled by scooping up the grease.

Oils and Greases. The variety of oils and greases recommended for automobile use is so extensive, and there are so many cheap and worthless lubricating compounds on the market, that it is almost impossible for the purchaser without technical knowledge to discriminate between them. The various tests from time to time recommended, whereby the user may ascertain for himself the quality of the lubricant he is using, are rarely of positive value, since the compounders of the shoddy oils and greases are usually sufficiently expert chemists to concoct admixtures that will successfully pass such simple tests as are available to the average layman, and will fail only under the more critical analysis of a competent chemist, or under the severe and more risky practical demonstration that results from long use, in the course of which the worthlessness of the lubricant is apt to be found out only at the cost of serious injury to the mechanism.

The consequence is that the only really safe policy to follow is the purchase of the highest grades of oils and greases, marketed by concerns of established reputation.

The oils generally found best for gasoline-engine cylinder lubrication are the mineral oils derived from petroleum, though castor oil is found to possess peculiar merits for the lubrication of air-cooled motors working at high temperatures, and in which there is often involved the friction of steel surfaces working over steel surfaces. This oil is exclusively employed in aviation motors, such as the Gnome, which is built with steel cylinders and pistons, and it is often utilized in racing automobile motors. Its chief merit seems to be that instead of withstanding the high temperatures, which is the result sought in the use of mineral oils of high fire test, it burns up clean without leaving any deposit upon the cylinder walls. It has to be fed in excessive quantities, which makes its use a rather expensive method of lubrication. But for the peculiar services for which it is adapted, it certainly proves most satisfactory.

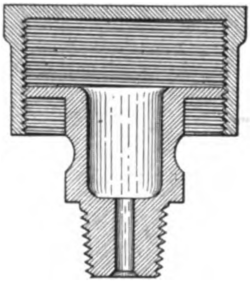

Fig. 55. Typical Grease Cup

In greases and oils used for the lubrication of parts not exposed to such high temperatures as prevail in gasoline-engine cylinders, the admixture of vegetable and animal greases and oils with mineral oils and greases is not objectionable and often may be of considerable benefit.

Graphite is a solid lubricant that it is very advantageous to employ in many parts of an automobile. In the deflocculated form, admixed in very small percentages with cylinder oils, gearbox greases, etc., there is no question but what it greatly conduces to smooth running and to long life of bearings. Its resistance to the very highest temperatures makes it constitute a considerable safeguard against immediate injury in case of neglect to replenish the lubricants as often as is properly required.

Principles of Effective Lubrication. To render lubrication positive and effective there are certain conditions regarding the design of bearings and the feeding of lubricants that must be scrupulously observed.

One of the commonest mistakes in this connection is the assumption that bearings should fit extremely close upon shafts. When such fits are attempted the almost invariable result is overheating and quick destruction of either bearing or shaft, or both.

The proper application of a lubricant to a revolving shaft, passing through a bearing, requires that definite space be provided between shaft and bearing for the lubricating material. The amount of this space varies with the size of the shaft, the speed of rotation, and other conditions, but in a general way it can be specified that the space must be greater as the shaft diameter increases, and greater for heavy oils and low speeds than for light oils and high speeds. For the crank shafts of automobile engines, to take a specific example, it is rarely desirable to have the bearing smaller than from .0005 to .0015 inch larger than the shaft. The annular space thus provided, as suggested at *A* in the end and sectional views in Fig. 56, is occupied by the lubricant, which, contrary to another general impression, will not be squeezed out unless the shaft is loaded above its capacity, which is more apt to occur from the bearing area being too small than from any other condition likely to be encountered.

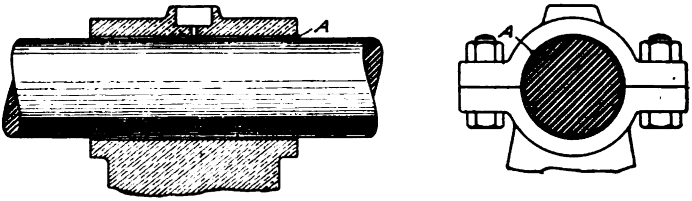

Fig. 56. Condition of Bearing for Proper Lubrication

With the bearing area large enough, which means that the specific pressure on its projected area must not be excessive, the tendency of the oil to remain in its place by capillary attraction perhaps helped by the pressure under which it is fed into the bearing, is much greater than the tendency of the load upon the shaft to force it out.

From the foregoing, it will now be evident that the condition of effective lubrication is that in which the shaft literally floats in an oil film of microscopic thickness, completely surrounding it and so protecting it from any contact whatever, under normal conditions, with the bearing surface. Wherefore the necessity for accurate fitting of bearings is not to secure a close metal-to-metal contact, as is sometimes erroneously supposed, but to provide the necessary oil film of a uniform instead of an irregular thickness.

BEARINGS

As the portion of a mechanism upon which, more than upon any other element, its continued operation and long working life depends, the bearings of any piece of machinery should be of the most approved design and most perfect construction.

Plain Bearings. The conditions that determine the proper proportioning and fitting of plain bearings has already been referred to in a preceding paragraph.

The materials of plain bearings are commonly varied to meet different conditions. With liberal bearing areas, and in situations where it is desired to bring about a perfect fit with minimum amount of labor, and in addition to this to protect the shaft from wear in case there is failure of the lubrication, the various types of babbitt metal—which usually are alloys of tin and lead, with sometimes some admixture of antimony and other alloys—are widely regarded as the most serviceable. Probably the greatest advantage of a babbitted bearing is that, should the lubrication fail, the low melting point and the soft material of the bearing will insure its fusing out without injury to the more expensive and valuable shaft.

Brass and bronze bearings, particularly the phosphor bronzes and the bronzes in which the proportion of tin is high and that of copper low, with sometimes the admixture of a proportion of zinc or nickel, will allow the use of materially higher pressures per square inch than can be safely permitted on babbitted bearings.

Steel shafts in cast-iron bushings, and even in hardened-steel bushings, make much better bearings than one might think, and though immediate trouble is to be anticipated with such a bearing should its lubrication even momentarily fail, this is more or less true of any bearing that can be devised. And since steel-to-steel and steel-to-cast-iron permit much the highest loadings to the unit of area that are permissible with any types of metal-to-metal bearing, the merits of these materials are perhaps less appreciated than might be desirable. Steel pins through steel bushings, however, are a not uncommon construction for the piston-pin bearings in high-grade automobile engines.

Roller Bearings. Roller bearings, constituted by the interposition of pluralities of small rollers between shafts and casings, are a type of bearing widely employed in automobiles.

A much-favored construction is the tapered roller bearing illustrated in Fig. 57. This stands up very well under both thrust and radial loads.

Another type of roller bearing is that illustrated in Fig. 20, in which the rollers are small flexible coils made of strip steel, finally hardened and ground accurately to size. This type of roller can be depended upon to work without breakage or injury even though there be considerable deflection or inaccuracy in the alignment of shaft or casings, the flexibility of the individual rollers taking care of such small errors.

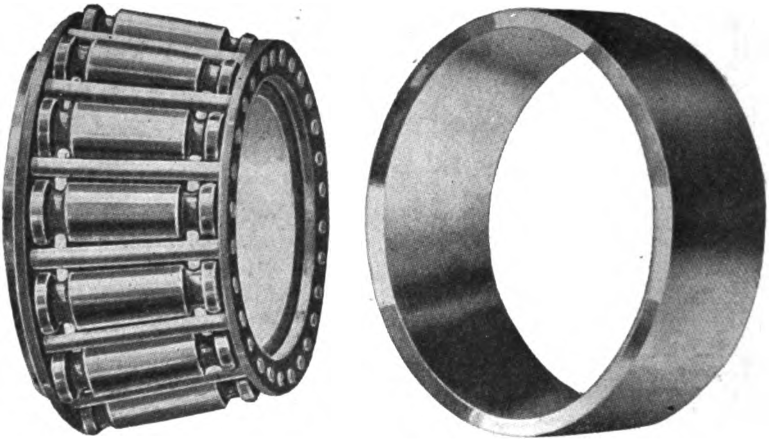

Fig. 57. Timken Roller Bearing
Timken Roller Bearing Axle Company

Ball Bearings. Probably the best of all bearings, except for certain special applications in which it is difficult to utilize them in sufficiently large sizes to assure durability, are the annular ball bearings of the general type illustrated in Figs. 58 to 62, inclusive. The basic feature of the most successful of modern annular ball bearings is their non-adjustability, the balls being ground very accurately to size, and closely fitted between the inner and outer races so as to allow practically no play, but at the same time without any arrangement whatever for adjustment such as was provided in the earlier cup-and-cone bearings of bicycle practice.

The reason that the best ball bearings are not made adjustable is that, in any conceivable type of ball bearing, one or the other of the races rotates and the other remains in a fixed position. The result is that there must be a loaded side to the race that does not rotate, with the consequence that when wear occurs, it wears the ball track deeper at this point than on the unloaded side. And, with the bearings thus worn, and any provision for adjustment, the attempt to adjust can result only in tight and loose positions as the balls come in and out of the spot that is more deeply worn.

This condition has led the designers and manufacturers of the various types of high-grade annular ball bearings that are now on the market, to discard adjustment as of no value, and to substitute in its place qualities of material and hardness of surface which, in combination with the provision of sufficient sizes, are found to reduce wear to so small an amount that it is almost inappreciable, and a bearing thus made can be therefore depended upon to outlive almost any other part of the mechanism in which it is placed.

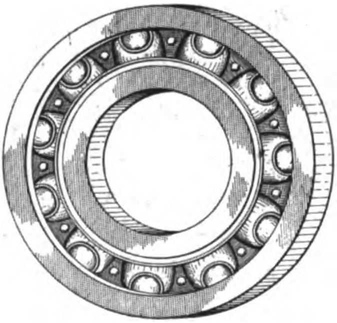

Fig. 58. Annular Ball Bearing

The carrying capacities of ball bearings, as compared with those of roller bearings, are much greater than a casual consideration might lead one to suppose. Theoretically the contact of a roller bearing—between a roller and one of the races—is a line contact, while that between a ball and a ball race is a point. But practically, since some deformation occurs in even the hardest materials under sufficient load, the line contact in the roller bearing becomes a rectangle and the point contact in the ball bearing becomes a circle. Now the vital fact is that the area of the rectangle in the one case is substantially equal to that of the circle of the other—with given quality of materials and a given loading. So a ball bearing is fully as capable of carrying high loads as a roller bearing, besides which it avoids the risk of breakage that usually exists with rollers, because of the impossibility of making them perfectly true and cylindrical.

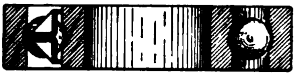

Fig. 59. Section of Annular Ball Bearing

To assemble ball bearings of the type illustrated in Fig. 59, either of two expedients may be adopted. One is to notch one or both of the ball races, so that by slightly springing them a full circle of balls can be introduced through the notch. The other scheme is to employ only enough balls to fill half of the space between the races, which permits them to be introduced without any forcing, after which they are simply spaced out at equal intervals and thus held by some sort of cage or retainer, such as is illustrated in Fig. 60.

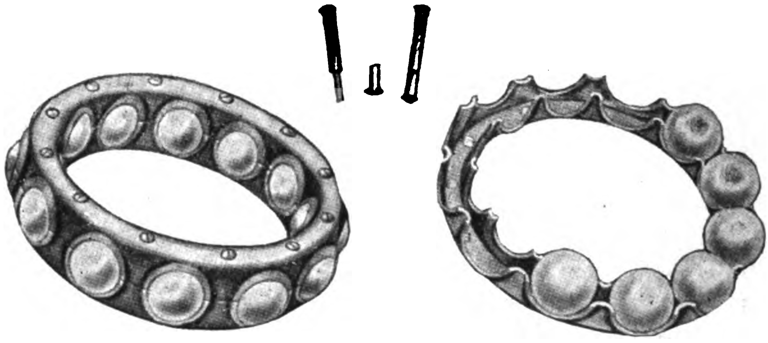

Fig. 60. Ball Cage of Annular Ball Bearing

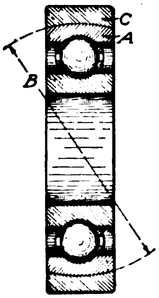

Fig. 61. Bearing Designed to Equalize Loads

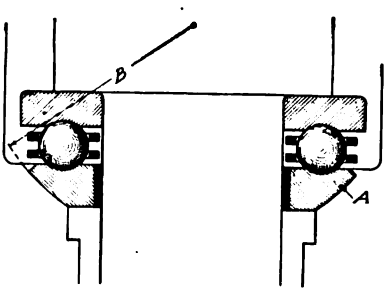

Fig. 62. Annular Ball Bearing Mounted for Thrust Loads

Ball bearings of the common annular type are quite serviceable to sustain end thrust as well as radial loads. For the best results under such loads, however, it is essential that the load be distributed equally around the entire circle of balls, for which reason the system illustrated in Fig. 61 is a means of avoiding the unequal distribution of pressure apt to result from the slightest inaccuracy of fitting. In this construction the outer ball race, shown at *A*, is provided with a spherical outer surface, permitting it to rock slightly in the mounting *C*, into the position shown in an exaggerated degree at *B*. It thus floats automatically to a position at exact right angles to the shaft upon which it is mounted, and so insures even loading of the whole ball circle.

An annular ball bearing designed for thrust loads alone is illustrated in Fig. 62. In this the lower race *A* is provided with a spherical face, described from the radius *B*, so that, as in the case of the bearing illustrated in Fig. 61, when in use it automatically floats under the load into such a position that all of the balls are under equal pressure.

To secure uniformly satisfactory results from ball bearings it is not only necessary in the first place to have them of the best materials, accurately made, and of sufficient sizes, but thereafter they must be always protected from dust and grit, and from water and acids which tend to cause rust. Also, they must be kept lubricated.

IGNITION

To no portion of the automobile power plant has more study been devoted than has been bestowed upon the ignition system. And yet in spite of the thousands of dollars that have been expended and the innumerable systems that have been tried, it probably is safe to assert that there remains no element of the complete automobile power plant that is more prolific of trouble than some of the ignition systems that are still in use.

Low Tension and High Tension. There are two principal types of ignition systems in common use for automobile engines. The essential distinction between these lies is their use of low-tension or high-tension current.

A typical low-tension system is illustrated in Fig. 63. In this *A* is the battery (a magneto, dynamo, or any other suitable source of current may be used), *B* is a spark coil, and *C*, *D*, and *E* are the elements of a make-and-break device that is mechanically actuated at regular intervals by the motor itself to produce the sparks within the cylinder. As shown in the drawing, the circuit is completed by grounding the wires from one side of the battery on the cylinder base, or any other portion of the machine, as at *F*. In the construction sketched, *B* shows a small insulated plug entering the interior of the cylinder, usually through one of the valve caps, while *C* is a movable arm that makes and breaks contact with *B*, at the point *E*, when it is given a slight rocking movement. For the best results this rocking movement must be very sharp and rapid, in the nature of a snap, and it must, of course, be correctly timed to occur in proper relation to the moment when the spark is required.

Many different systems have been devised and used for the effective and reliable operation of make-and-break devices of the character illustrated, but the most reliable usually prove to be the simplest.

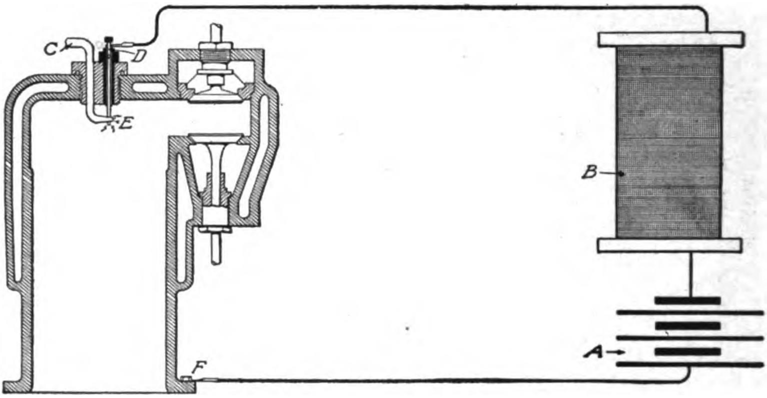

Fig. 63. Diagram of Low-Tension Ignition System

The chief advantage of low-tension ignition is its immunity from troubles caused by short-circuiting by leakage of the current through poor insulation, or across moistened terminals. This consideration has caused it to be extensively employed in motorboat motors, where there is much exposure to wet, but for automobiles high-tension ignition is generally preferred, though there are one or two prominent manufacturers who remain staunch adherents of low-tension ignition.

A characteristic system of high-tension ignition is diagrammed in Fig. 64, in which *A* is the battery—or other suitable current source—placed in a primary circuit that also includes the contact maker *C*, the primary winding of the coil *B*, and the vibrator *G*.

The contact maker *C* is positively driven by a connection with some revolving part of the motor, so that it makes contact at the exact time ignition is required in each cylinder.

With a system of the type described, when contact is made the first result is attraction of the vibrator blade *E* by the magnetized core *H* of the coil. This, by drawing *E* away from the contact screw *G*, at once breaks the primary circuit again, and this demagnetizes *H*, with the result that *E* again springs into contact with *G*. The effect of this is to cause a rapid series of current surges through the coil *B*, as long as the contact maker *C* maintains the contact.

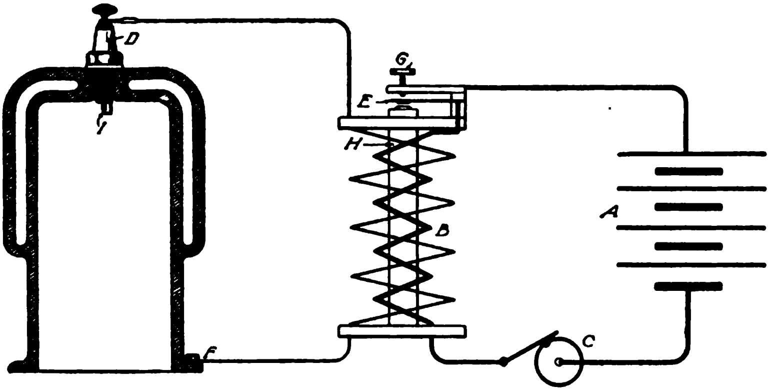

Fig. 64. Diagram of High-Tension Ignition System

Each time a surge of primary current passes through a coil a secondary current of very high voltage is induced in the secondary circuit, which is grounded on the cylinder at *F* and connected at *B* with the spark plug. This plug, for high-tension ignition, has an open gap of about $\frac{1}{32}$ inch at *I*, across the resistance of which gap the current will jump, because of its high tension.

Ignition is thus effected by a rapid succession of sparks across *I*.

Magnetos. Because of the nuisance of recharging storage or primary batteries, and the short life and not infrequent unreliability of dry cells, the best present-day ignition systems of both the high-tension and low-tension varieties are supplied with current generated by magnetos positively driven by the engine during all of the time that it is in operation.

A magneto is simply a small dynamo in which the field magnets, instead of being electro-magnets wound with wire, are permanent magnets of hard steel.

Most magnetos are so arranged, with two-pole magnets and a two-pole armature, that they afford two surges of current to each revolution, and in consequence they are geared with the engine in a relationship corresponding to the number of cylinders and the frequency of the explosions in the cycle. Thus, in a four-cylinder, four-cycle motor, in which there are two explosions to each revolution of the crank shaft, the magneto is commonly run at crank-shaft speed.

In most systems of electrical ignition it is necessary, or at any rate desirable, to have some means of "advancing" the ignition. In a low-tension system of the type illustrated in Fig. 63, the advance is usually cared for by mechanical means for varying the moment of snapping the contact breaker *C*. In a high-tension ignition system, of the type illustrated in Fig. 64, the spark lever on the steering wheel is arranged to control the moment of contact in the contact maker *C*.

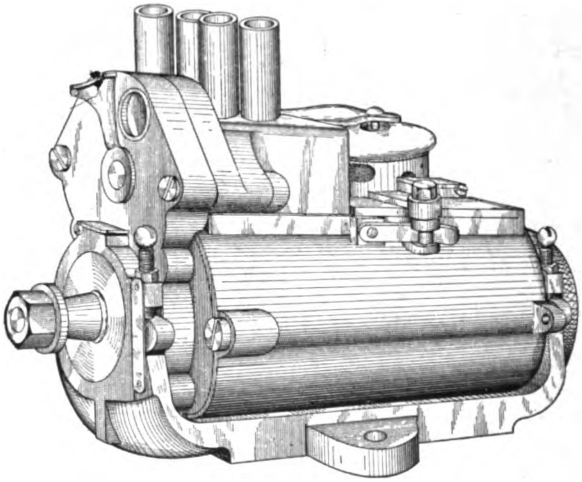

Fig. 65. Mea Magneto in Trunnion Mounting

There is a dual reason for the advance of ignition. First is the fact that an explosive mixture requires the lapse of some definite time after the moment the spark occurs for it to get into full combustion.

In the opinion of some engineers, the foregoing, especially with poorly-compounded mixtures of undue richness or leanness, possibly justifies ignition slightly before the piston gets to the top of the stroke, to insure the mixture being in full combustion after the piston has passed over top center and entered upon the working stroke of the cycle.

A more important reason for advancing ignition, however, is found in the mechanical and electrical lags that exist in practically all ignition systems. These lags, even if only as brief as one two-hundredth of a second, may coincide with a very considerable portion of the crank-shaft revolution in a motor working at high speed. With a motor running at 2,400 revolutions a minute there are 40 revolutions, or 80 strokes, per second, so during one two-hundredth of a second the crank shaft turns 72 degrees. Obviously, then, with such an ignition system, and at such a rate of speed, it will be necessary to have the time of commutator contact 72 degrees before the end of the stroke if the spark is to occur at dead center. Moreover, as the speed of the motor changes and the number of degrees of crank-shaft rotation that correspond to one two-hundredth of a second thus varies, there must become apparent the perfect reasonableness of advancing and retarding the moment of commutator contact solely to *maintain*, rather than to *change*, the time of ignition.

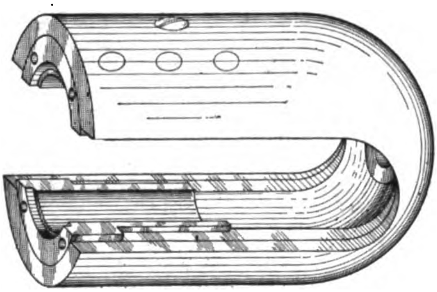

Fig. 66. Bell-Shaped Magnet of Mea Magneto

In some magneto systems of ignition the mechanical and electrical lags are reduced to such insignificant amounts that it is possible with these systems to dispense with the necessity of spark advance, though there is some question as to whether slightly better results can not be always secured, even in these cases, by the use of it.

One of the most successful four-cylinder magnetos made is illustrated in Fig. 65, in which the magneto proper is shown mounted on trunnions in a frame so that it can be rocked back and forth in its frame to vary the moment of ignition.

The magnets of this magneto are shown in Fig. 66, from which they will be seen to consist primarily of two hardened-steel elements, one within the other.

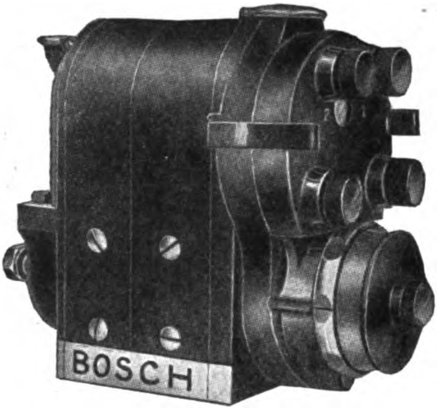

Fig. 67. Bosch Enclosed Type Magneto

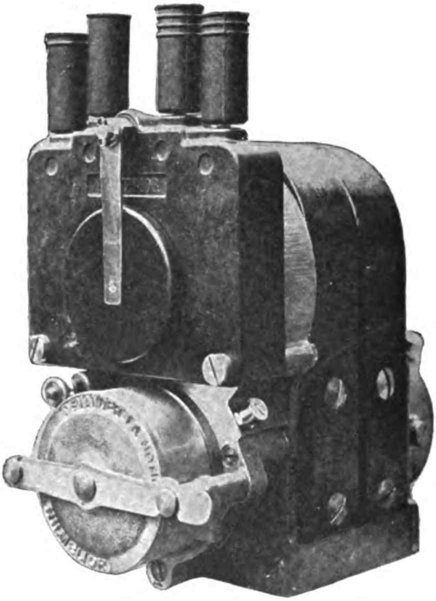

Fig. 68. Front View of Nilmelior Magneto
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In Fig. 67 is illustrated a U & H magneto, which is one of the best-known and most widely-used types.

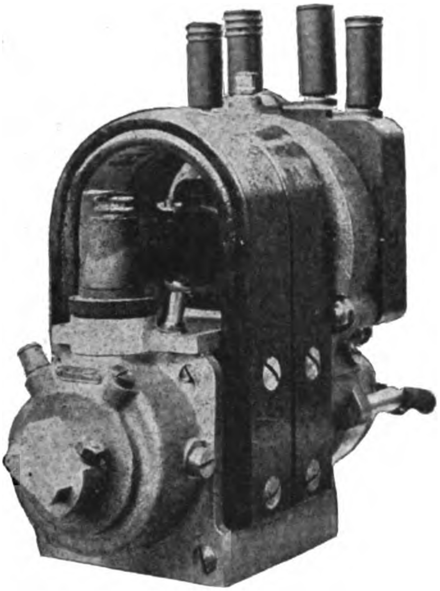

Fig. 69. Back View Nilmelior Magneto
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Another well-known and successful magneto is the Nilmelior magneto, .of which front and back views are shown in Figs. 68 and 69. This magneto, like the Bosch magneto shown in Fig. 67, employs ordinary U-magnets, built up of four separate parts.

In Fig. 70 are diagrammed the circuits and the essential parts of a high-tension magneto system, using the magneto shown in Fig. 65.

In this system *C* and *B* the wires of the primary circuit, in which circuit there are also included, besides the current-generating coils of the armature, an induction coil built into the magneto, for raising the current tension, and a contact breaker *E,* which is carried on the same revolving spindle that bears the armature.

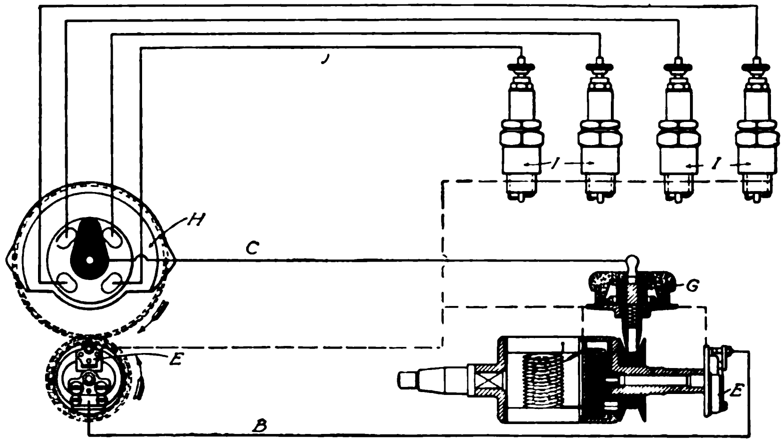


Fig. 70. Wiring Diagram of High-Tension Magneto System

In the diagrammatic representation given in Fig. 70, this contact breaker is shown in a side view at the right and in an end view at the left. At *G* is a connection in the primary circuit, which through a carbon brush bearing against a brass collector ring that is borne on the armature, is kept constantly closed at this point despite the revolution of the armature.

At regular intervals, 180 degrees apart—twice in each revolution of the armature, and at the moment when the current surges induced by the poles of the armature passing the poles of the magnet are at their maximum—the contact breaker *E* comes into play and definitely times the current surge that passes on through the secondary wire to produce the ignition spark at one or another of the spark plugs *I*. To insure the spark always occurring in the proper cylinder the four wires *J* are momentarily connected up, one after another in proper sequence, by the distributor *H*.

Batteries. Batteries, though preferred by few to a magneto as the source of current, are still used in some ignition systems, especially in those of cheaper cars.

The most inexpensive battery equipment consists of dry cells, usually six in number, but with most ignition systems the maintenance of dry cells as a current source, involving frequent replacement, is much more expensive than the use of storage batteries, which, though they cost more in the first instance, can be cheaply charged and do not require charging very frequently.

Dry Cells. The term dry cell is really a misnomer, since a cell of this type consists simply of a zinc element constituting the case of the cell, a carbon element centered within this, and an electrolyte composed of a moist paste of suitable chemicals. The top of the cell is commonly sealed with pitch or wax compound to prevent the moisture from evaporating, and if by any chance the cell does become really "dry," its usefulness is then at an end.

Storage Cells. Another misnomer, to the extent that it conveys a wrong impression to many minds, is the term "storage" as applied to certain types of electric batteries.

In these batteries the current is generated by the chemical action of an acid electrolyte upon elements composed chiefly of plates of lead oxide, or by the action of an alkaline electrolyte upon nickel and iron elements. As such a cell exhausts itself there is, as in any primary cell, a chemical rearrangement of the elements involved in the production of the current. And instead of any actual "storage" of electricity when such a battery is recharged by passing an electric current through it, the condition is simply that the charging current, by an electrolytic action, recomposes the chemicals in their original condition, so that the cell is again ready for a period of use.

For automobile ignition systems, storage cells are usually used in batteries of three, connected in series, and consequently affording a current at about six volts.

Primary Cells. Cells of this type, with the exception of dry cells, which, of course, are one form of primary cells, are little used in automobile ignition. The one type that has found some application is the Edison-Lalande primary cell, with a few others of similar character, for which the charging chemicals are supplied in convenient and measured units, ready for quick replenishing when the cell goes "dead."

In motorboat power plants, primary cells of the type referred to in the preceding paragraph are rather extensively used.

Coils and Vibrators. As has already been explained in the descriptions relating to Figs. 63 and 64, induction coils for intensifying or raising the voltage of the current are necessary in both low-tension and high-tension ignition systems.

For good results, an automobile ignition coil should be very carefully made, the many adjacent turns of very fine wire requiring the most careful insulation to avoid internal short circuits. In the best coils, of silk-insulated wire of the highest quality, after the coil is completed it is placed in a wooden box and the box is then filled with molten paraffine which, upon solidifying, greatly improves the quality of the insulation.

Vibrators, of the type illustrated at *E*, *G*, and *H*, Fig. 64, consist simply of the thin blade of spring steel at *E*, provided with an armature at the free end to intensify the attraction of the coil *H*, and adjacent to the adjusting screw at *G*, by which the distances between the contact points can be accurately set. In addition to these elements it is usual to provide a screw adjustment for increasing or reducing the tension of the vibrator blades.

Contacts in the best vibrators are made of platinum, or, better still, of platinum-iridium alloys, which are very hard as well as extremely resistant to the very high, though brief and localized, temperatures of the small arcs that form across the terminals each time the contacts are separated. In cheaper coils, German silver, silver, and other metals often are much used for contact points, but the only advantage of these over platinum or platinum alloys is their lower price.

As is explained hereinafter, present practice in the design of ignition systems is towards the elimination of the vibrator, especially from a plurality of coils.

For example, the arrangement illustrated in Fig. 71, which shows four coils, each with an independent vibrator, designed for the ignition system of a four-cylinder motor, is very objectionable in that it is practically impossible to adjust all of the vibrators the same. And since any variation in adjustment results in a corresponding variation in magnetic and mechanical lags, with the result that the timing from one cylinder to another will vary, perceptible differences in the power output of the different cylinders, resulting in uneven running, are produced in the different cylinders.

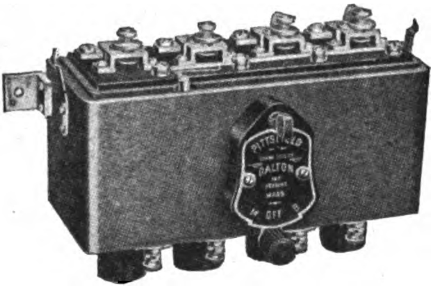


Fig. 71. Pittsfield Multi-Vibrator Coil
Pittsfield Spark Coil Company, Dalton, Massachusetts

Master vibrators—only one for a number of cylinders—are a much better construction than the foregoing.

Nevertheless, the use of any vibrator at all is really unreasonable, since it has been proved impossible to make a trembler blade work at faster than 200 or 300 vibrations a second, against which it has been shown in a preceding paragraph that such an interval of time may represent a very considerable distance of crank movement. From all this it is reasonable to infer that, if the first spark occurring after the contact maker has come into action does not produce ignition, then the next spark, even with the vibrator working at its highest speed, will be too late to be of material benefit.

Contact Breakers. Because of the objection just discussed, to the use of vibrator and multi-vibrator coil systems, non-vibrator coil systems employing "interrupters" of the type illustrated in Fig. 72, have been found to constitute a marked improvement. Interrupters of the character here used are different from those used in vibrator coils in that they afford a tremendously sharp and brief period of contact, with an abruptness of make-and-break that is not secured by any other device. The consequent effect is to produce a very strong current surge, with a strong spark, but of the briefest possible duration.

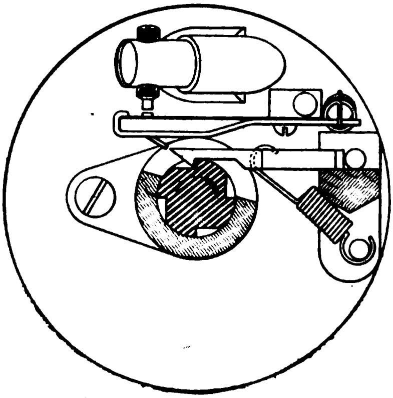


Fig. 72. Atwater-Kent Interrupter
Atwater-Kent Manufacturing Works, Philadelphia, Pennsylvania

The advantage of the brief duration is that great current economy is realized. The fact that only one spark is required for each ignition is an important contributing element to this economy.

Because of these features, non-vibrator high-tension systems, such as that illustrated in Fig. 73, and provided with interrupters of the type shown in Fig. 72, are far and away the most economical in current use of all the systems used for automobile-engine ignition. Instances are on record of automobiles with these systems having been run distances of as great as 1,000 and 1,200 miles, on six dry cells of the tiny types commonly used in pocket flash lights. Indeed, the

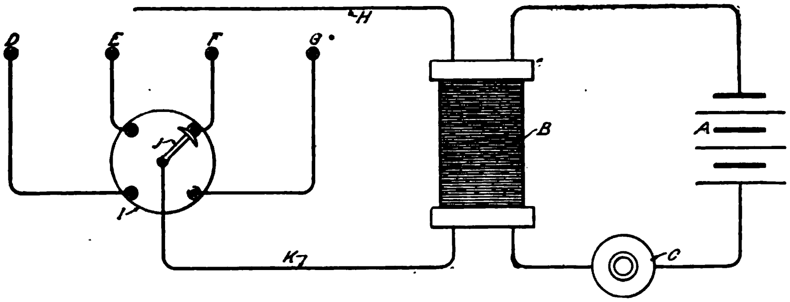


Fig. 73. Wiring Diagram of Non-Vibrator High-Tension System

economy of current with these systems is so extreme that the source of current ceases altogether to be a problem. As one result, these battery systems are the strongest competitors of magneto systems, over which they possess the advantage that self-starting by manipulation of the spark is possible, as is not the case in any but a very few of the magneto systems, in which means are provided for jerking the magneto armature around by hand to afford the initial spark, before the engine has started running.

In the diagram presented in Fig. 73 the primary circuit includes the battery *A*, the interrupter *C*, and the primary winding of the coil *D*. In the secondary circuit there is nothing but the ground wire *H*, and the wire *K* to the secondary distributor *I*, from which the current is distributed by the distributing arm *J* to the four plug wires *D*, *E*, *F*, and *G*.

Distributors. For distributing a secondary current to the different plugs of a set, on a multi-cylinder engine, it is always necessary in a high-tension ignition system to have some sort of a secondary distributor. This is the case in magneto as well as in battery systems, and in Figs. 65, 67, 68, 69, and 70, as well as in Fig. 73, it is to be observed that in every case there is to be discerned some equivalent of the distributor *I*, indicated in Fig. 73. In magnetos, which as a rule deliver rather lower tension than is employed in battery systems, a carbon brush wiping over brass contact segments imbedded in vulcanite insulation constitutes the commonest means of distributing the secondary current.

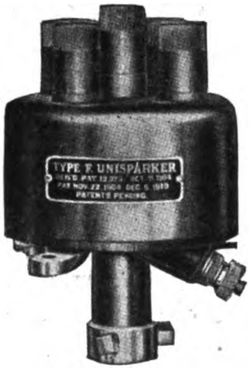


Fig. 74. Atwater-Kent Distributor

In many battery systems, such as that illustrated in Fig. 73, it suffices to have the distributing arm *J* approach very closely to the end of the plug wire terminals, with a slight gap or clearance between. This small gap offers no serious obstruction to the passage of the high-tension current, and in consequence actual rubbing contact is not necessary.

A four-cylinder distributor for a high-tension battery system, of the gap type instead of the contact type, is illustrated complete in Fig. 74.

Spark Plugs. For low-tension ignition systems, in addition to the type of contact breaker illustrated in Fig. 63, built into the cylinder, there also are used to some extent various types of magnetic plugs, such as that illustrated in Fig. 75, in which *C* is a steel rod that is lifted by the magnet *B* when its winding *A* is energized by the current. This separates the contacts at *D* and causes the spark at the proper moment, when the magneto is delivering its maximum current.

An objection to such plugs is that they must be very carefully protected from overheating, or else the high temperature will burn the insulation of the wiring at *A*.

A typical high-tension spark plug, of well-known make, is illustrated in Fig. 76. In this plug there is a plurality of gaps for the current to jump, though the current always takes the path across the shortest space. As the points wear away with use, however, the spark shifts around from one point to another, and so a much greater life without readjustment is secured in the use of a plug with plural terminals of this type.

Testing, Adjusting, and Maintenance. Automobile users as a rule know less about the ignition systems than about almost any other part of a car. This fact, in combination with the fact that ignition systems are subject to obscure ailments, which are difficult to diagnose, tends to make ignition troubles numerous and serious.

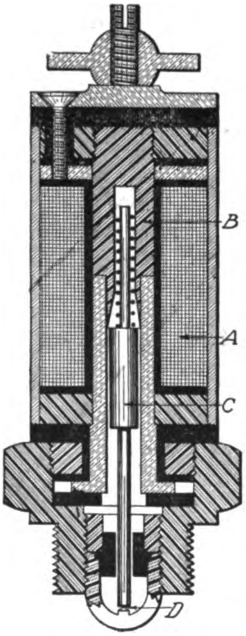


Fig. 75. Low-Tension Magnetic Spark Plug

Nevertheless, with the knowledge of a few rudimentary facts, and consistent observation of a few simple rules, ignition trouble can be greatly minimized.

To commence with, it always is necessary to be sure that the current supply is of the necessary voltage, particularly if batteries are used. With batteries, a voltmeter always should be kept handy, to test the voltage of the cells. This is more important with storage cells than with dry cells, and for the latter a good ammeter is perhaps more practical for ordinary work and in unskilled hands than a voltmeter.

With a reading of 17 amperes or over, through an ordinary pocket ammeter, a dry cell can be safely assumed to be in good-enough condition to afford reliable ignition.

The best way for the average person to take care of a magneto is to leave it severely alone, except for regular oiling in the amounts and at the points stipulated by the manufacturer. The repair of the average magneto is a difficult job, and should be undertaken only by a competent expert, in a fully-equipped repair shop.

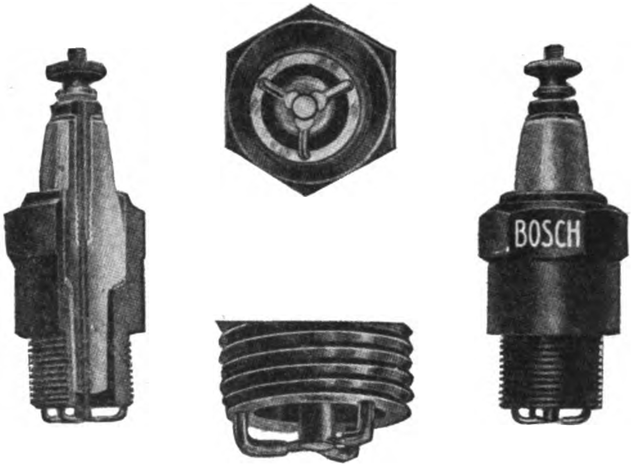


Fig. 76. Bosch High-Tension Spark Plug

Occasionally, however, magneto trouble is due to short-circuiting of the contact plates in the secondary distributor, due to the smearing of oil and carbon dust by the movement of the distributing brush. In such a case it is a simple matter to take the distributor apart and carefully wipe all of its parts clean. The same method should be followed if it is suspected that the trouble has been caused by the entry of moisture into any of the magneto parts.

The gap in spark plugs should range from $\frac{1}{64}$th to $\frac{1}{32}$d of an inch, the latter distance being as great as is ever desirable.

Magneto systems require rather closer adjustment of the plug points than is necessary in battery systems, because of the rather lower voltages secured with magnetos.

ELECTRIC LIGHTING

For automobile headlights, side lamps, tail lamps, and general illumination, electric lighting is rapidly superseding the at-one-time-popular acetylene gas systems, which require either a large amount of attention, if acetylene generators are used, or a frequency of replacement, if gas tanks are used, that are causes of much annoyance and trouble.

In the best electric lighting systems the current is supplied by dynamos driven constantly by the engine, with a storage battery to supply current when the motor is stopped. The system thus is completely self-contained and illumination is always on tap, regardless of any source of supply outside of the car. The facility with which electric lights can be switched on and off, avoiding the troubles of lighting up in a wind, which are so unpleasant with gas or oil lamps, is not the least of the advantages of electric lighting.

Incandescent Lamps. Lamps of this type are at present the only ones used in automobile lighting, the various types of arc, exposed-filament, and other electric lamps being totally unsuited to the conditions—involving much exposure to vibration and the necessity of securing the desired result from low-voltage current—which are practically inseparable from the problems of automobile lighting by electricity.

Tungsten and Other Filaments. Incandescent lamps with carbon filaments were the first used for automobile lighting, but since incandescent lights of this type consume about two and a half times as much current for a given amount of illumination as is required by the modern metallic-filament lamps, of the tungsten and other types, these are rapidly giving way to the improved form, in automobile lighting as well as for other classes of illumination.

The objection to tungsten filaments—that they are rather frail, and thus tend to break with slight vibration—while it applies in the ordinary use of these lamps in units of 25 candle-power and up, is not especially valid with reference to automobile lighting, in which much lower candle-powers are used. The filaments, therefore, are much shorter and much stronger than in standard lamps, a condition that is further contributed to by the necessities of low voltage and high amperage, which in themselves require short and thick rather than long and thin filaments. Moreover, recent improvements in tungsten filaments have made them of much greater strength than were used in the first tungsten lamps placed upon the market.

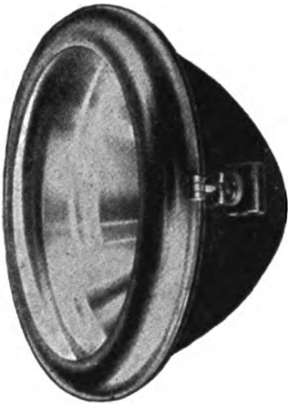


Fig. 77. Typical Electric Automobile Headlight

A good tungsten lamp will afford one candle-power of illumination for each 1.2 watts of current. A carbon lamp takes 3.5. So, for example, an ordinary 80-ampere-hour storage battery, delivering current at eight volts, will without recharging keep two 8-candle-power headlights burning for about twenty hours.

This is a long enough period to make practical even the restorage and interchange of batteries, though a dynamo in the car to keep them constantly recharged without replacement is indisputably much better.

Reflectors. Much attention has been directed to the problem of defining the best type of reflectors for automobile headlights and the conditions of lighting by acetylene gas have been determined to be very different from those involved when electric lighting is used.

Locomotive Type and Other Reflectors. A typical electric headlight for automobile use is that illustrated in Fig. 77, in which the construction is seen to be of the utmost simplicity. The plain form affords a minimum tendency to catch dirt and mud and greatly simplifies cleaning. A finish of black enamel over most of the lamp, with simply a nickel-plated rim holding the front glass, makes a very neat appearance and avoids the necessity for frequent polishing.

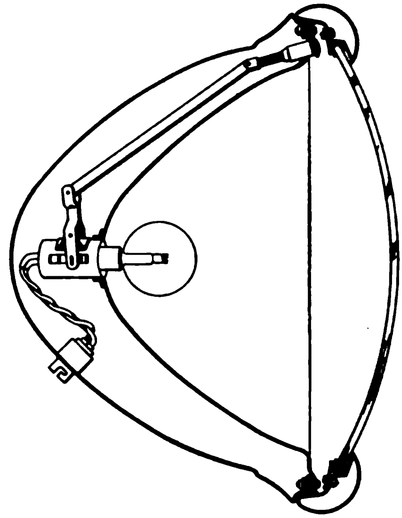


Fig. 78. Section of Fig. 77

The reflector in the foregoing lamp is of the deeply-parabolic metal type, illustrated in Fig. 78. The advantage of this type of reflector is that it intercepts a much larger proportion of the light rays from the lamp than the lens-mirror type of reflector shown in Fig. 79. Thus, while the mirror type of reflector—made of a glass lens of considerable thickness, silvered on the back—has a higher reflecting efficiency than metal reflectors, except when the latter are freshly polished, the fact that it intercepts so little of the total light available results in its projecting in the beam a correspondingly small proportion of the total light available.

Furthermore, the difficulty of tarnishing, which rapidly occurs with metal reflectors when gas flames are used, is largely avoided with electric lights, because with electric lamps placed in the reflector cavity the whole can be so closely sealed that tarnishing progresses at a very slow rate. But even with its reflecting surface at less than its full efficiency, the manner in which the deep metal reflector extends way forward over the light source causes it to intercept so much higher a proportion of the light rays that the total amount of light projected will average far greater than with the gas flame and a lens mirror.

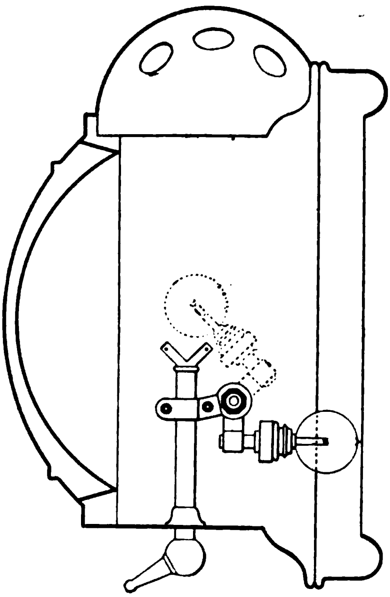


Fig. 79. Mangin Lens Reflector

The reason that electric lights of 8 candle-power can be made to afford as concentrated and powerful a beam as a 16 or 25 candle-power acetylene flame is that the filament of the electric light, from which all of the illumination proceeds, can be coiled in much smaller space, and thus located closer to the focus of the reflector than is possible with an acetylene flame, the great area of which tends to produce a more diffused light because by far the greater proportion of the flame is out of the focus of the reflector, wherefore its light is not projected as a concentrated beam.

Lighting Batteries. The only type of batteries suitable for electric ignition—except for very small tail lamps, which can be successfully kept in operation by dry cells—are storage batteries of the lead or Edison types.

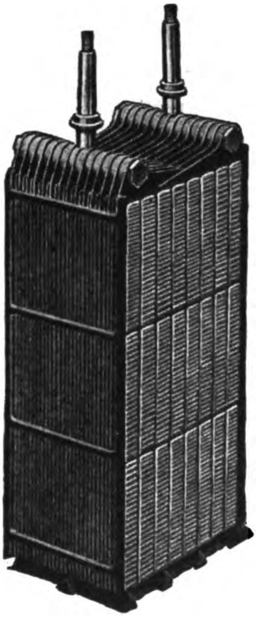


Fig. 80. Complete Edison Cell

Lead storage batteries have been already referred to in the discussion of sources of ignition current.

The Edison battery, a five-cell example of which is illustrated in Fig. 80, while it is less efficient—in the ratio between current required for charging and current delivered in discharging—and also is of lower voltage than the lead cell—about 1.2 volts against 2.2 volts—has the merit of a much greater durability and a practically complete immunity from troubles due to overcharging and overdischarging.

Dynamos. A typical lighting dynamo, arranged to be run from the motor that propels the car, and adapted to deliver current directly either to lamps or to batteries, is illustrated in Fig. 81.

This dynamo, which weighs less than twenty pounds, and a sectional view of which is shown in Fig. 82, is of the most simple character, and it is driven through the intervention of a releasing clutch automatically controlled by a mechanical governor. The effect of this clutch is to permit a slipping drive whenever the dynamo speed exceeds 1,200 revolutions a minute, so that the voltage can never rise above normal and burn out lamps or injure the battery.

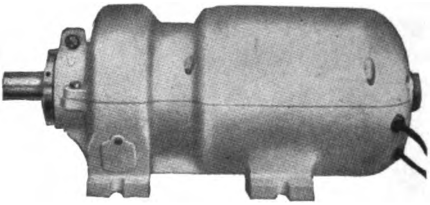


Fig. 81. Gray and Davis Lighting Dynamo
Gray and Davis, Boston, Massachusetts

Current Control. In lighting systems involving the use of a dynamo such as that illustrated in Figs. 81 and 82, and with a storage battery for furnishing current when the car is stopped or running at so low a speed that the current delivered by the dynamo is not of sufficient voltage to keep the lamps up to their maximum efficiency, there is involved, among the other devices, means for switching both dynamo and batteries in and out of action, as circumstances may demand. In some of the most successful systems in which the battery is "floated on the line," if the car is stopped or run at low speed the lamp circuits are automatically supplied from the battery alone and connection with the dynamo is switched off, so that the batteries can not discharge current through the wiring of the dynamo.

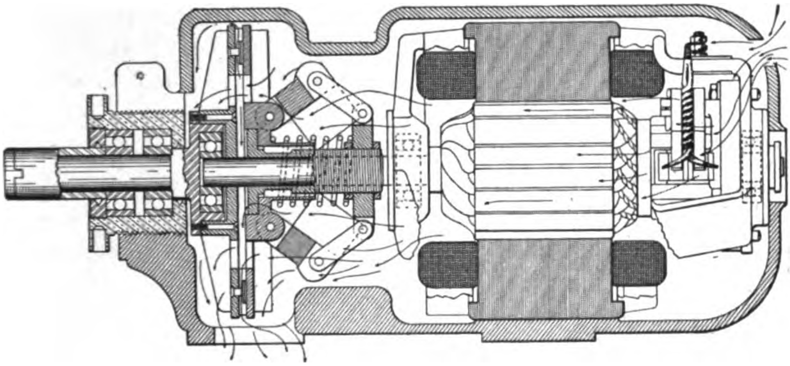


Fig. 82. Section of Gray and Davis Lighting Dynamo

As the motor is put into operation, and speeds up to a point where the dynamo can deliver current of a proper voltage, this current serves the dual use of recharging the batteries, if they are in any degree discharged, and of keeping the lamps burning. When the batteries are sufficiently charged, so that further charging would injure them, automatically the charging current is switched off and the lamp supplied by dynamo current alone.

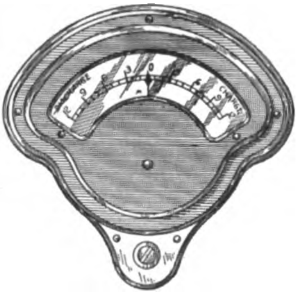


Fig. 83. Gray and Davis Voltmeter

And, as has been already explained, if the motor speed rises so high that it would otherwise drive the dynamo too fast, the clutch mechanism then comes automatically into play and permits a certain amount of slipping—sufficient to prevent the speed of the dynamo from rising above its normal.

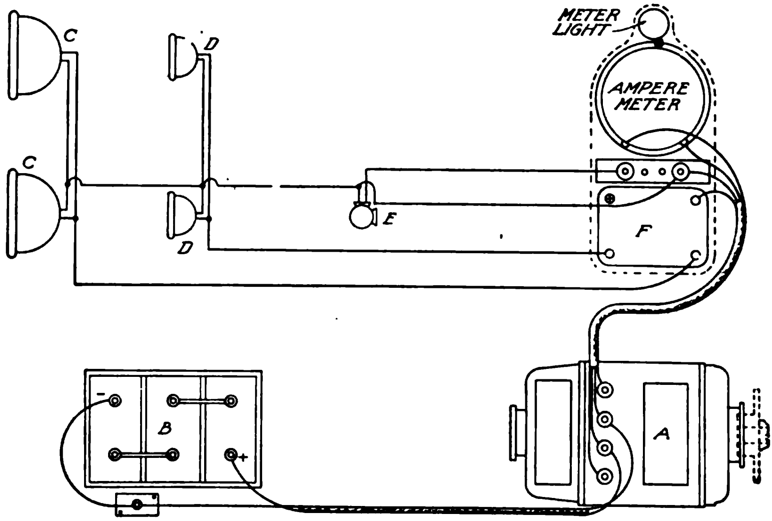


Fig. 84. Dyneto Wiring Diagram for Automobile Lighting Circuit
Dyneto Electric Company, Elbridge, New York

A voltmeter, for indicating the condition of a storage battery—showing whether or not it needs recharging—is illustrated in Fig. 83. This particular voltmeter is one that is used in a well-known and very successful system of electric lighting for automobiles.

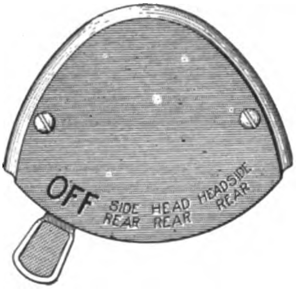
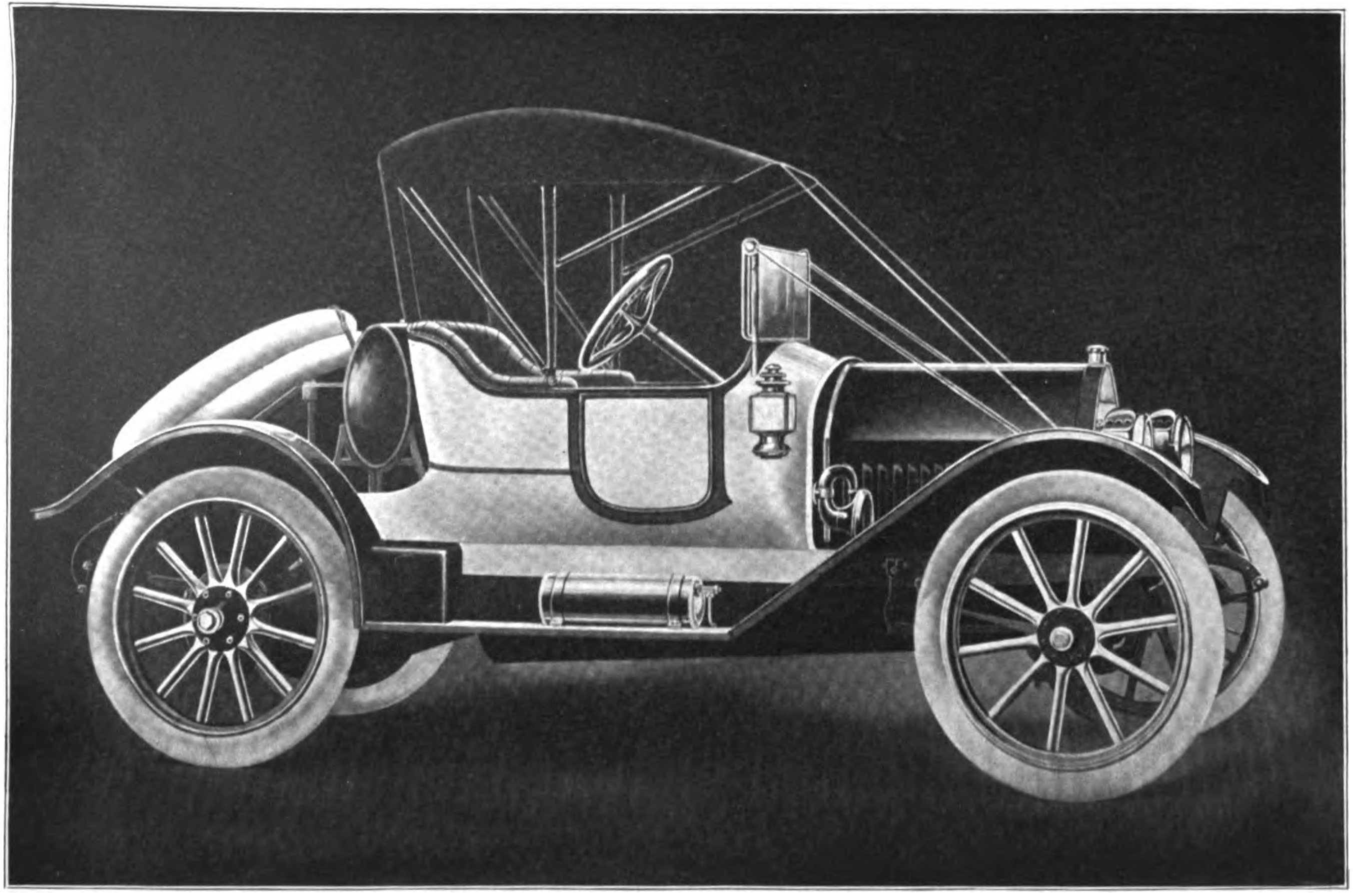


Fig. 85. Typical Three-Point Switch

Wiring and Switches. The wiring diagram of an automobile lighting system such as that just described, is illustrated in Fig. 84, in which *A* is the dynamo, *B* is the storage battery, *CC* are a pair of head lamps, *DD* are side lamps, and *E* is the tail lamp. *F* is a switch of the type illustrated in Fig. 85, by means of which either the head lamps and the tail lamp alone can be lighted, the side lamps or the tail lamps alone, or all five lamps together.

In addition to the foregoing combination, many automobile lighting systems also include provision for switching on dome lights in the interior of closed bodies, dashboard lamps for illuminating speedometers, lubricators, etc., and connections for "trouble lamps," on lengths of flexible cords, for examining different portions of the mechanism inside the bonnet, underneath the car.



CARTERCAR MODEL R ROADSTER WITH FRICTION DRIVE

Cartercar Company, Pontiac, Michigan

GASOLINE AUTOMOBILES

PART II

VALVE GEARS

Probably the most important thing about a four-cycle, gasoline engine is the valve, or more correctly, are the valves, for the usual number is two per cylinder. The opening and closing of these control the functions of the engine, for if the valve does not open and allow a charge of gas to enter, how can the piston compress and the ignition system fire a charge? Similarly, if the exhaust valve is not opened and the burned gases allowed to escape, they will mingle with and dilute the fresh, incoming charge, possibly to the extent of making the latter into a non-combustible gas. This is purposely stated in this way because both methods mentioned have been utilized for governing the engine speed, although not to any great extent in automobile work.

Cams. Granting, then, the necessity for proper means to regulate the inflow and outgo of the charge and consequent products of combustion, as exemplified by the valves, the next most important part is the one which controls the movement of the valve, and is, therefore, essential to the success of the latter. This is what is known as a *cam* and in the usual case amounts to an extension of or projection from the so-called *cam shaft.* Inasmuch as the valve functions only come into play upon every other stroke of the crank shaft, this cam shaft is gear-driven from the crank shaft, so as to rotate at half the speed of the latter. This is very simply effected by having the cam gear twice as large as the crank-shaft gear, that is, with twice as many teeth. As the same valve is never used for both the inlet and the exhaust, so the cams are seldom made to do more than the one thing, namely, operate one of the valves. From this has grown the custom of referring to them according to the function of the valve which they operate—*inlet cam, exhaust cam,* etc.

In laying out or designing a set of cams for a gasoline engine,

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TABLE I

Timing Regulation of a Number of Prominent French Motors

Nos.		Lead of Exhaust Opening	Lag of Inlet Closing	Ignit. Advance	Lag of Exh. Closing	Lag of Inlet Opening	Relation of Conn. Rod to Radius Crank	R.p.m. at Full Power
1	Ours	55°	20°	var.	0°	15°	4.76	1 000
2	Charron.—20/30 h.p., 1908	44°	0°	—	0°	1°	4.55	1 100
3	Rossel.—40 h.p., 4 cylinders	38°	23°	—	0°	2°	4.29	1 100
4	Gregoire.—10/14 h.p., 4 cylinders, 1908	53°	0°	—	0°	5°	4.18	1 200
5	Motobloc.—24 h.p., 100/120 1908	45°	10°	—	5°	10°	4.75	1 200
6	Panhard-Levassor	45°	40°	—	0°	0°	4.5	1 200
7	Hotchkiss.—4 cylin. 95/100	44°	33°	—	10°	17°	4.27	1 300
8	Cottin-Desgouttes.—18/22 h.p	46°	30°	38°	8°	15°	4.15	1 300
9	Brouhot.—12 h.p., 4 cylinders, 75/110	45°	45°	30°	0°	20°	5	1 300
10	Cornilleau-Ste-Beuve.—20/30 h.p., 1908	56°	20°	43°	6°	20°	4.62	1 300
11	Mutel.—40 h.p., 1908	62°	21°	var.	28°	26°	4.4	1 300
12	Berliet.—22 h.p., 1908	48°	38°	—	9°	17°	4.5	1 300
13	Peugeot (*Paris*).—18/24 h.p. 1908	58°	18°	38°	0°	10°	4.76	1 300
14	Labor.—20/30 h.p	51°20′	0°	var.	0°	0°	4.18	...
15	Luc Court	45°	0°	—	15°	30°	4.25	...
16	Brasier	45°	25°	34°	0°	7°	4.5	1 350
17	Peugeot (*Beaulieu*)	51°30′	58°	31°	20°	15°	4.78	1 400
18	Aster.—9 h.p., 105/120	40°	40°	var.	0°	0°	4.3	1 400
19	Rochet-Schneider.—24 h.p., 100/120	40°	20°	20°	0°	20°	4.75	1 400
20	De Dion-Bouton.—12 h.p., 4 cylinders, 1908	45°	45°	30°	0°	0°	4.7	1 400
21	Eudelin	36°	20°	var.	4°	8°	4.3	1 450
22	Farcot.—14 h.p., 80/100	36°	10°	—	2°	6°	4	1 500
23	Chenard-Walcker	36°	36°	—	0°	0°	5.25	1 500
24	Darracq.—10/12h.p., 100/120	48°	30°	21°	0°	0°	4.5	1 500
25	Aries.—14/18 h.p.	58°	44°	20°	13°	18°	4.91	1 500
26	Vinot-Deguingand.—12/16 h p., 80/110	30°	15°	27°	0°	15°	4.54	1 500
27	Sultan.—9/12 h.p., 4 cylinders, 75/110	58°	42°	32°	14°	22°	4.55	1 600
28	Renault.—8 h.p., 2 cylinders	32°	26°	33°30′	10°	23°30′	4.33	1 600
29	Unic.—20 h.p., 75/110	53°	40°	30°	10°	34°	4.5	1 650
30	Sizaire et Naudin.—15 h.p., 120/110	44°	37°	var.	0°	15°	5.25	1 700
31	Larrad Device	52°	17°	—	22°	17°	....	.....
	Average	46°20′	26°15′	—	5°40′	8°6′	....	.....

The motors are arranged in this table in the order of their increasing speeds. The angles are figured in degrees, counting from the nearest dead center. "Var." means that the point of ignition may be advanced or retarded by the driver.

such as is used on an automobile, it is first necessary to decide upon the exact cycle upon which to operate the engine. By this is meant the exact length of time, as referred to the stroke, in which the valve action will take place. Upon this subject, designers all over the world differ, and no wonder, as this cycle can but be judged by results, for it is impossible to watch it as it transpires. Deductions differ, therefore, as to what happens, and consequently, as to the effect of various angles of beginning and ending of the valve actions.

Tables of Valve Settings. Some time ago a table of the valve settings used by the foremost French car designers, was compiled and is here given, Table I, as a basis of comparison with the valve data of American types, Table II. In studying these tables, it should be borne in mind that all angles are spoken of in terms of the crank shaft, and are usually referred to the two dead centers, commonly spoken of as the *upper dead center* and the *lower dead center*.

Now, if the average of the numerous examples of good practice be taken, it is not a hard matter to explain the form of the cam and

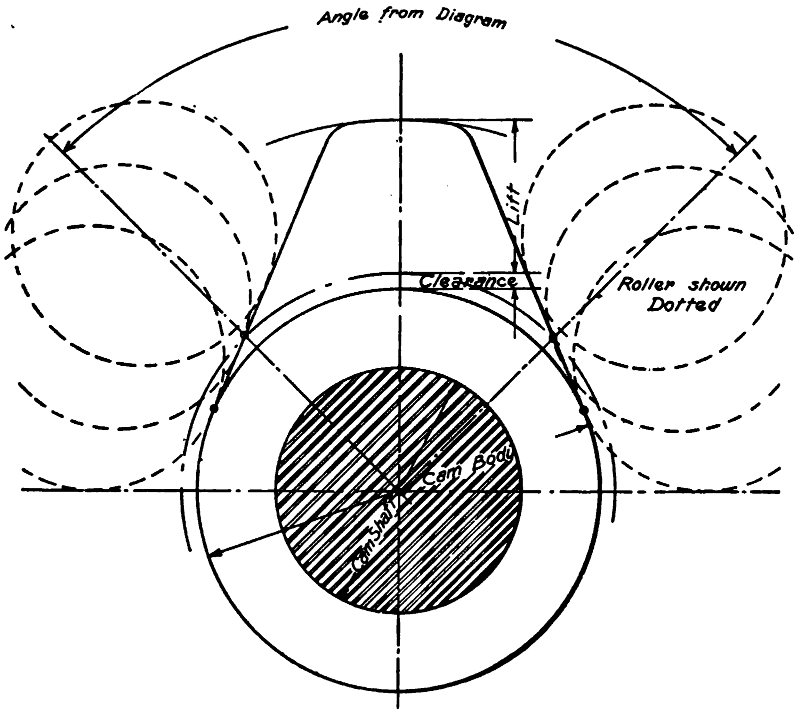


Fig. 86. Method of Laying Out Cams

its derivation. The height of the upper surface of the highest part of the cam above the surface upon which the valve actuating device normally rests, determines the *lift* of the valve, which is the name given to the amount it is opened or lifted. This is not really the lift of the valve because of the fact that in all valve operating systems there is a certain amount of clearance between the lower end of the valve stem and the upper end of the valve lifter mechanism. This

TABLE II

Timing Angles for Maxwell Motors and Other Data of Interest

MODEL	TIMING OF VALVE IN DEGREES AND EQUIVALENTS OF INCHES ON FLYWHEEL								Diam. of Fly-wheel	Stroke of Cyl-inder	Diam. of Cyl-inder	No. and Type of Cyl-inders	H.P. of One Cylin-der	Normal Speed Rev. per Min.	Max. Speed Rev. per Min.
	INLET				EXHAUST										
	Opens		Closes		Opens		Closes								
	Degrees	Equiv.	Degrees	Equiv.	Degrees	Equiv.	Degrees	Equiv.							
L..........	15° late	2 3/8″	40° late	6 1/4″	40° early	6 1/4″	10° late	1 9/16″	18″	4″	4.5″	2 horiz.	6	800	1200
H..........	15° late	2 5/8″	40° late	7″	40° early	7″	10° late	1 3/4″	20″	5″	5″	2 horiz.	8	750	1000
Q..........	15° late	2.289″	40° late	6.104″	40° early	6.104″	10° late	1.526″	17 1/2″	4″	3.75″	4 vert.	4.5	900	1400
K..........	15° late	2.487″	40° late	6.633″	40° early	6.633″	10° late	1.691″	19″	4 1/4″	4.25″	4 vert.	6.5	800	1200
M..........	15° late	2 5/8″	40° late	7″	40° early	7″	10° late	1 3/4″	20″	5″	5″	4 vert.	10	800	1200

NOTE—In timing valves, piston should be on upper dead center.

clearance must be taken up by the cam before the valve itself is actually lifted, so, to obtain the true lift, the amount of the clearance is subtracted from the lift as determined by the cam height. Knowing this, designers usually predetermine the clearance and allow for it in the height of the cams.

Cam Design. In order to lay out a set of cams, not only must the cycle be fixed, but the clearance as well. Fig. 86 shows the way to go about this; the size of the shaft is simply determined, and if other means fail, the empirical formula may be used:

$$\text{Cam shaft diameter} = .625\,D - \tfrac{1}{8}''$$

in which D is the clear diameter of the valve opening in inches.

Having the cam-shaft diameter fixed, lay it out and about it circumscribe the cam thickness. This may be from one-eighth of an inch, upon very small, light-weight engines, to three-eighths inch on larger and heavier motors. Around this, in turn, describe another circle, distant from the cam surface a distance equal to the clearance. A fourth circle representing the height is shown only partly complete.

From the cycle previously determined upon, the total angle of inlet valve opening, for instance, is found by simple addition and subtraction; thus, if the inlet is to open 10 degrees past the upper center and close 20 degrees past the lower center, this makes the valve remain open a total of 190 degrees upon the crank shaft. As the cam shaft turns but half as fast, and therefore but half as far in the same length of time, for the cam this angle will be halved, or 85 degrees. Proceed to lay out half of this, or 42½ degrees, on each side of the vertical center line. A line forming this angle with the center line will intersect the line representing the clearance in a point. Through this point draw a line which will be tangent to the circle representing the surface of the cam, and prolong it upwards to meet the upper circle. Drawing in a round corner completes the cam lay-out. By sketching in the cam roller the progression is shown. Fig. 87 illustrates the complete valve motion. This is an example taken from actual practice, being the valve action as used on the Pierce-Arrow engines, made by the Pierce-Arrow Motor Car Company, Buffalo, N. Y. In the figure, *A* is the cam fixed on the cam shaft. As the latter rotates, and the higher part of the cam comes uppermost, the push rod *B*, the roller *C* of which bears on the face of the cam, is constrained to rise. The rising is opposed by the valve spring *F*, which is compressed by the rising between the two collars, one, *G*, being held in the valve stem *E* by the key or pin shown in section at *H*. The other, *I*, is fixed in the valve rod guide *J*, whose

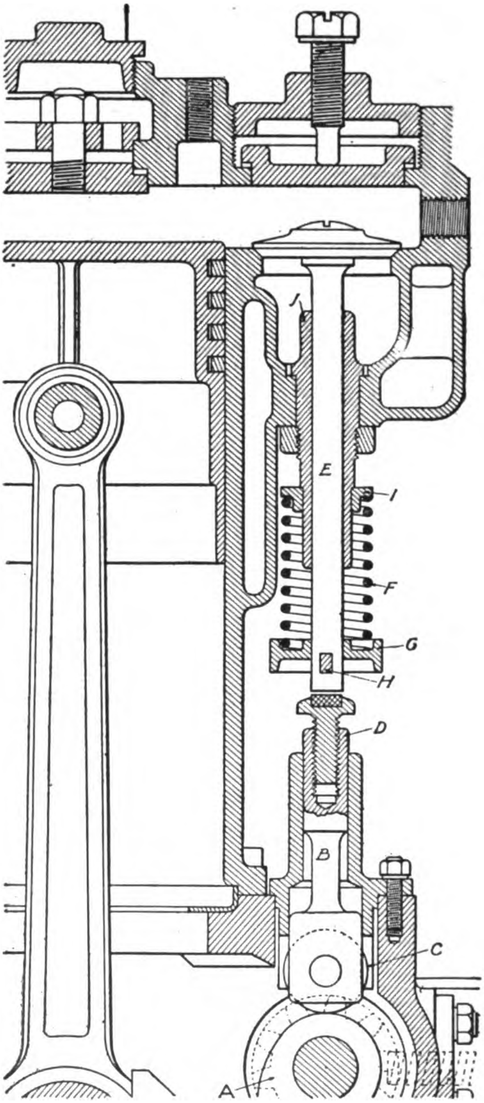


Fig. 87. Complete Valve Motion—Cam Shown at *A*
Pierce Arrow Motor Company, Buffalo, N. Y.

function is to guide the valve upward in a straight line. The roller *C* is of hardened steel as is also the cam face, but despite this, wear occurs and when it does is likely to effect the lift of the valve. To take account of this and always give the same amount of lift to the valve, the push rod is fitted with an adjustment at its upper end. This, marked *D* in the figure, consists of a bolt threaded into the upper end of the push rod and having a hardened steel insert in its central point of contact with the end of the valve stem. To retain the correct relation between the two, when it has once been obtained, a lock nut is utilized. While this is actually the exhaust valve, the same construction applies to the inlet valve mechanism, the parts of the two being interchangeable. This same line of reasoning and this same method of procedure, when followed in the case of the *exhaust cam*, will result in giving it the correct shape.

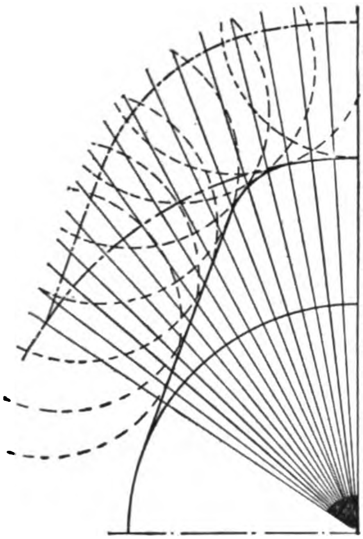


Fig. 88. Straight-Sided or Ordinary Cam

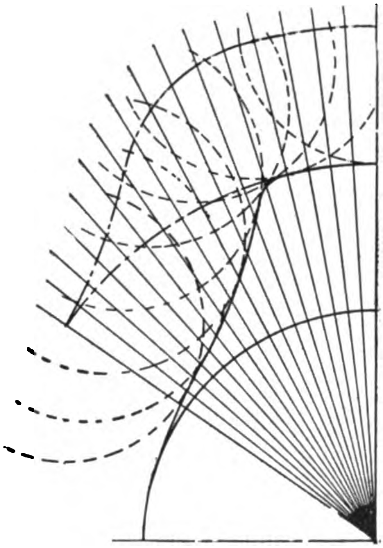


Fig. 89 Lay-Out for Uniform Acceleration Cam

It has many times been tried and still more often urged that the straight surface of the side of the cam is not conducive to the best results, because of the fact that when the first straight portion of the cam surface strikes the cam roller it does so with so much force that it tends to wear the latter in that direction. As for the receding face, it has been urged that the ordinary closing of the valve is too slow, and that the straight surface, as shown in Fig. 88, could be altered so as to allow of speeding up the downward movement of the valve. This idea works out into a curve, Fig. 89, the back of the surface being hollowed out so that as soon as the cam roller passes the center it drops vertically, due to the tension of the spring. This method has been tried but without success.

What Good Modern Practice Shows. A more modern way, which is fast becoming universal, is to use straight sides for the cams and take advantage of rapid closing in another way, the benefits of which more than offset the benefits of the old way, while having no corresponding disadvantages. In the ordinary automobile engine running at 1,000 revolutions per minute, the gases are traveling into the cylinder at the rate of 5,000 to 6,000 feet per minute, and traveling out at from 7,000 to 10,000 feet per minute. At this tremendous speed, the gas inertia is very high, and experiments go to show that the gases by means of this inertia will continue to force their way into the cylinder even against the return motion of the piston. So it is now common practice to hold the inlet valve open about 20 degrees on the up-stroke of the piston, which results in a much larger piston charge. The same practice is carried out with the exhaust, but as the pressure is higher, so large an angle is not necessary. These actions take place on the *back*, flat side of the cam surface, and have given to the high-speed automobile engine

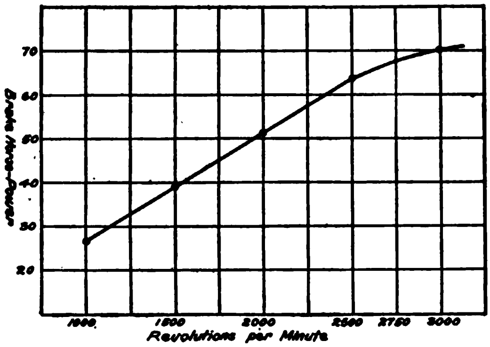


Fig 90. Power Curve of an English Engine with Superior Cams

a larger charge and a more complete scavenging effect, resulting in more power and speed from the same sized cylinder.

As proof of this statement, the power curve of an engine of but 4-inch diameter of cylinder is shown in Fig. 90. This size of four-cylinder engine would be rated by any formula at about 25 horse-power at the maximum speed, and a commercially obtainable type in this size would doubtless be guaranteed to deliver between 20 and 25 horse-power. This engine, built for racing purposes, displays a power curve which continuously rises, a speed at which it would turn downward not having been obtainable in the tests. This curve shows also that the maximum power obtained was over 70, which is nearly three times the power of the ordinary engine of this same size. This result is ascribable to superior valves and superior attention to the valve angles as governed by the cams.

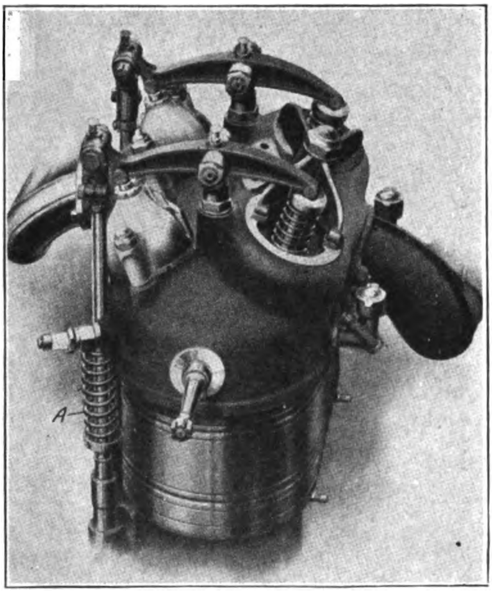


Fig. 91. Engine with Spring *A*, Doing Work of Cam. Formerly made by De Luxe Motor Car Company

When it was stated that but two valves per cylinder were ordinarily used, with one cam for each, the majority case was spoken of. But, as it is a fact that there are other cases which differ from this, it would not be fair to close the subject without mentioning them. Thus, the most prominent advocate of air cooling in this country and the world, the H. H. Franklin Manufacturing Company, uses three valves, and, consequently, three cams per cylinder. These three are: the ordinary *inlet;* the usual *exhaust;* and the additional *auxiliary exhaust.* As for the cams themselves, aside from their number, they do not differ from the ordinary.

One Cam per Two Valves Influences the Shape. A case in which the cam does differ is that of the use of two overhead valves operated from a single cam shaft, Fig. 91. This practice originated with the F. I. A. T. Company, which brought it out for racing use only, where it was particularly useful in that it halved the weight of the cam shaft, as well as saved much weight in push rods, etc. Later, this was taken up by other firms for regular use, although the company which first brought it out has never done so. In our own country, the device was adopted by the Pope Toledo Company, the Stoddard-Dayton, De Luxe, and others. The work of opening the extra valve is done by a spring, *i. e.*, a depression in the back of the cam allows a strong spring to pull the push rod down, by which process the valve stem is depressed and the valve opened. In Fig. 92 may be seen a variation of this method, the one cam operating both valves but being placed alongside of instead of on top of the cylinder castings. This form was used on

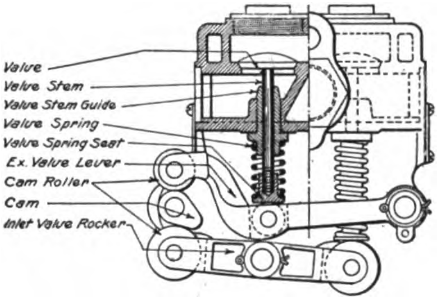


Fig. 92. Valve Motion with One Cam Opening Both Valves

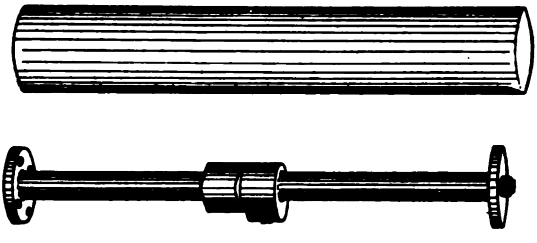


Fig. 93. Cam Shaft and Chrome Nickel Steel Billet from Which It Was Made

the Oldsmobile first four-cylinder cars. Fig. 93 shows how the cams for an overhead cam shaft may be machined up in a single piece, a pair of shafts like the one shown constituting the cam shaft of a four-cylinder engine. These are bolted together, the holes in the flange being plainly discernible. This shaft is made of very high-grade material and the method of making it in two pieces is resorted to in order to save as much of the material as possible. This method of procedure, of course, calls for a different treatment of the cam, for not only must the depression be put in its proper place, but it must be of the correct depth, and the point of its beginning and ending must be correctly determined.

When any kind of a cam-follower is used, differing from the usual direct lift push rod, as shown in Fig. 94, this may or may not affect the shape of the cam. Usually it does not, so that the shape does not have to be taken into account. Ordinarily these followers are used to prevent side thrust on the push rod guide, the follower itself taking all the thrust and being so designed as to be readily removable or adjustable, to take care of this. In cases where this does not obtain, the object usually sought is the removal of noise. The two objects may be combined as in the case shown in Fig. 95. This represents the cam and valve action of the famous one-cylinder French car, *Peugeot.* The enlarged view of the cam mechanism is added to the illustration to make clear the action, which is that of one cam operating both the exhaust and the inlet valves through the medium of a pair of levers, upon which the cam works alternately.

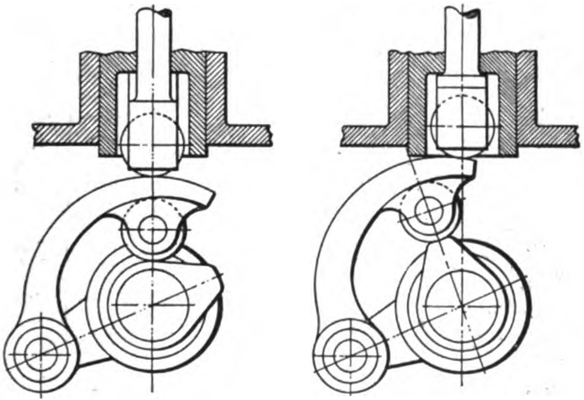


Fig. 94. Cam Design with Follower between Cam and Roller

It sometimes happens that the same maker does not use the same cam shapes upon all of his engines, although what is good practice in one case, would certainly appear to be good practice in another. That this does not hold is shown by Figs. 96 and 97, which illustrate the practice of the Maxwell-Briscoe Motor Car Company, previously referred to. Fig. 98 shows a double form of cam used to facilitate starting.

Difficulties Met with in Making Cams. Time was when the production of a good, accurate cam shaft was a big job in any machine shop, well-equipped or otherwise, and represented the expenditure of much money in jigs, tools, and fixtures. Now, however, the machine-tool builder has come to the rescue of the automobile manufacturer, and special tools have made the work easy. So it was with the production of the shaft with integral cams; this used to be a big undertaking, but today, special machinery has made it an easy

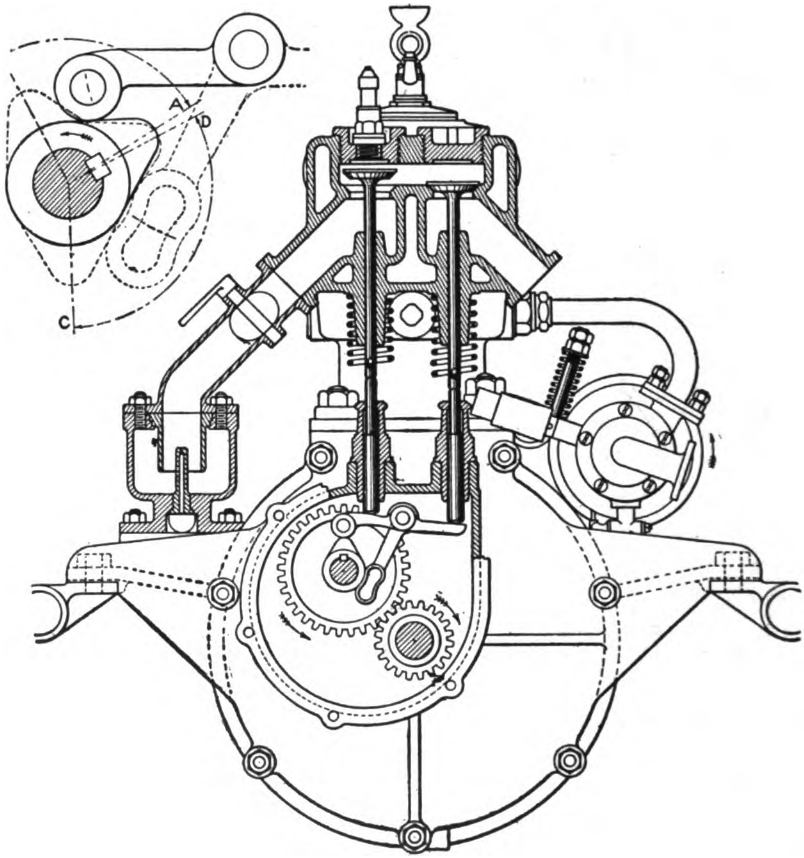


Fig. 95. Peugeot (French), Single-Cylinder Engine

matter. The illustration, Fig. 99, shows a cam milling machine, and Fig. 100 and Fig. 101, some of its product. This is now the favored way of putting out engines, for the integral cams and shaft have the advantage of much lower first cost, and with proper hardening, will last fully as long as those made by cutting the cams separately and assembling them in their proper position on the shaft.

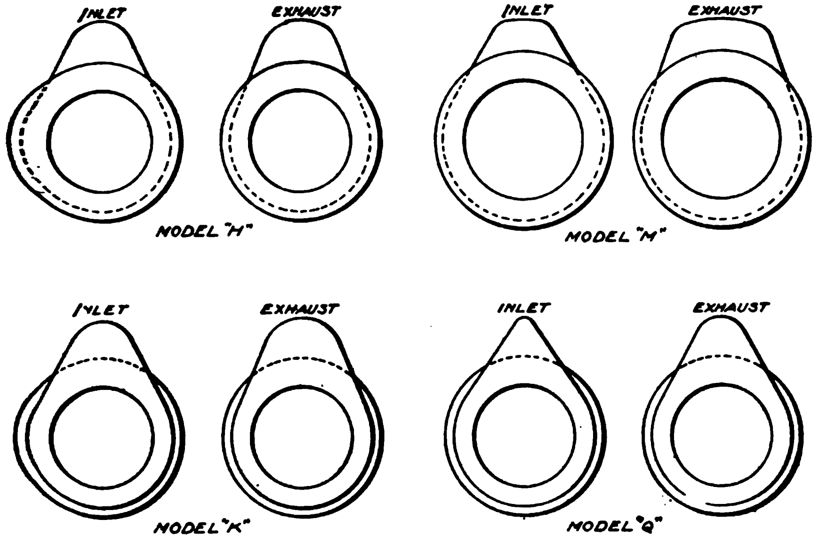


Fig. 96. Maxwell Cams
Maxwell-Briscoe Motor Car Company, Tarrytown, N. Y.

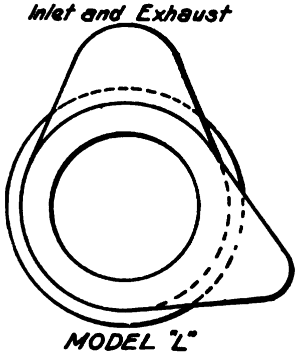


Fig. 97. Maxwell Inlet and Exhaust Cams

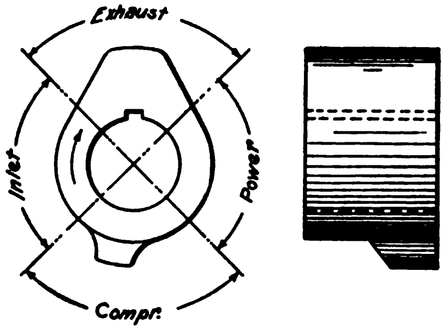


Fig. 98. Double Cam for Easy Starting

Old Way Required More Accurate Inspection. With the old method of making the cams and shaft separate, the amount of inspection work was very great and represented a large total expense in the cost of the car. Thus, it was necessary to prove up every cam separately, as well as every shaft, and later, the cams and shaft assembled. One of the forms of gauges used for inspecting cams is shown in Fig. 102. It is in two pieces, dovetailed together. This allows of the testing of many shapes of cam with but one base piece and a number of upper or profile pieces equal to the number of different cams to be tested. To test, the cam is slipped into the opening, and if small, the set screw forces it up into the formed part of the gauge, showing its deficiencies; while if large, it will not enter the form.

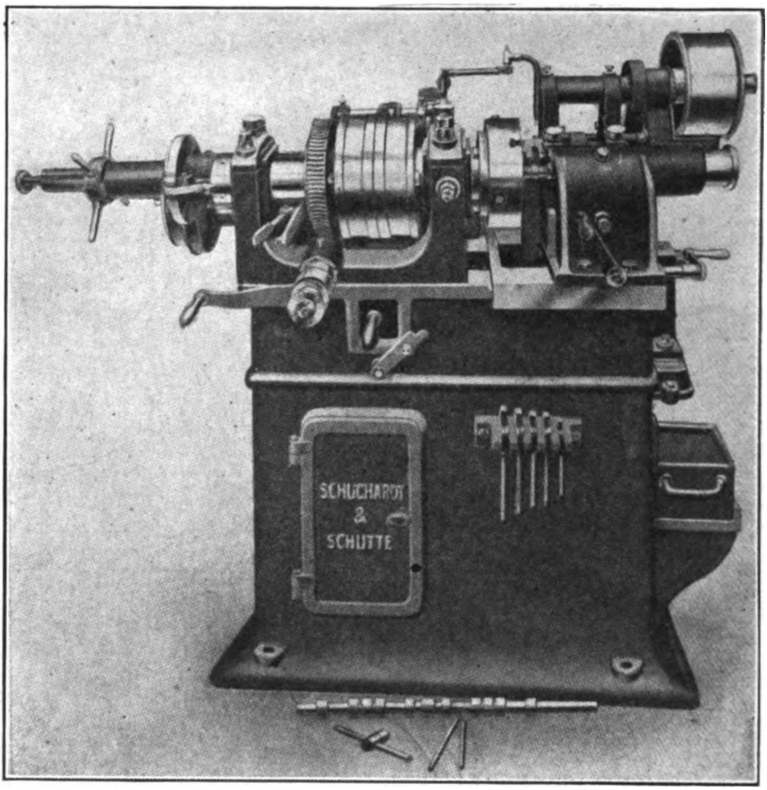


Fig. 99. Milling Machine for Making Cam Shafts with Integral Cams

Sliding Sleeve. A method of avoiding cams and with it all cam troubles, is the use of a *sliding sleeve* in place of a valve, slots in the sleeve corresponding to the usual valve openings, both as to area and timing. The sleeves may be operated by means of eccentrics, or by various lever motions. An additional way is the direct drive by means of a gear, a worm and gear being used for the purpose. An example of the application of this to a French two-cycle engine is shown in Fig. 103, although there is nothing in its construction which would prevent its use on the more usual four-cycle engine,

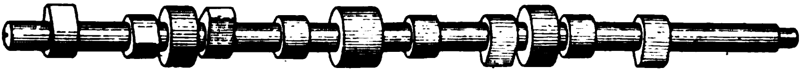


Fig. 100. Cams Integral with Shaft—Milling Machine Job

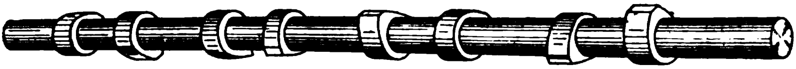


Fig. 101. Another Cam Shaft with Integral Cams

In this figure, *P* is the usual crank shaft, *Q* the large end of the connecting rod *K*, while *A* is the piston and *R* the crank case, no one of these differing from those in other engines. On the crank shaft there is a large gear *F*, which drives a smaller gear *E*, located on a longitudinal shaft above and outside of the crank case. On this shaft is located a worm gear *D*, which meshes with a worm *C* formed integral with the sleeve surrounding the piston *B*. Aside from this worm gear, the sleeve is perfectly cylindrical, being open at both ends. It is placed outside of the piston between that and the cylinder walls. At its upper end, it has a number of ports or slots cut through it, which are correctly located vertically to register or coincide with the port openings in the cylinder walls, when the sleeve is rotated. At *H* is seen one of these—the exhaust—while 90 degrees around from

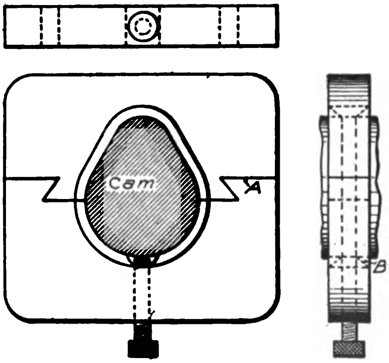


Fig. 102. English Cam Gauge

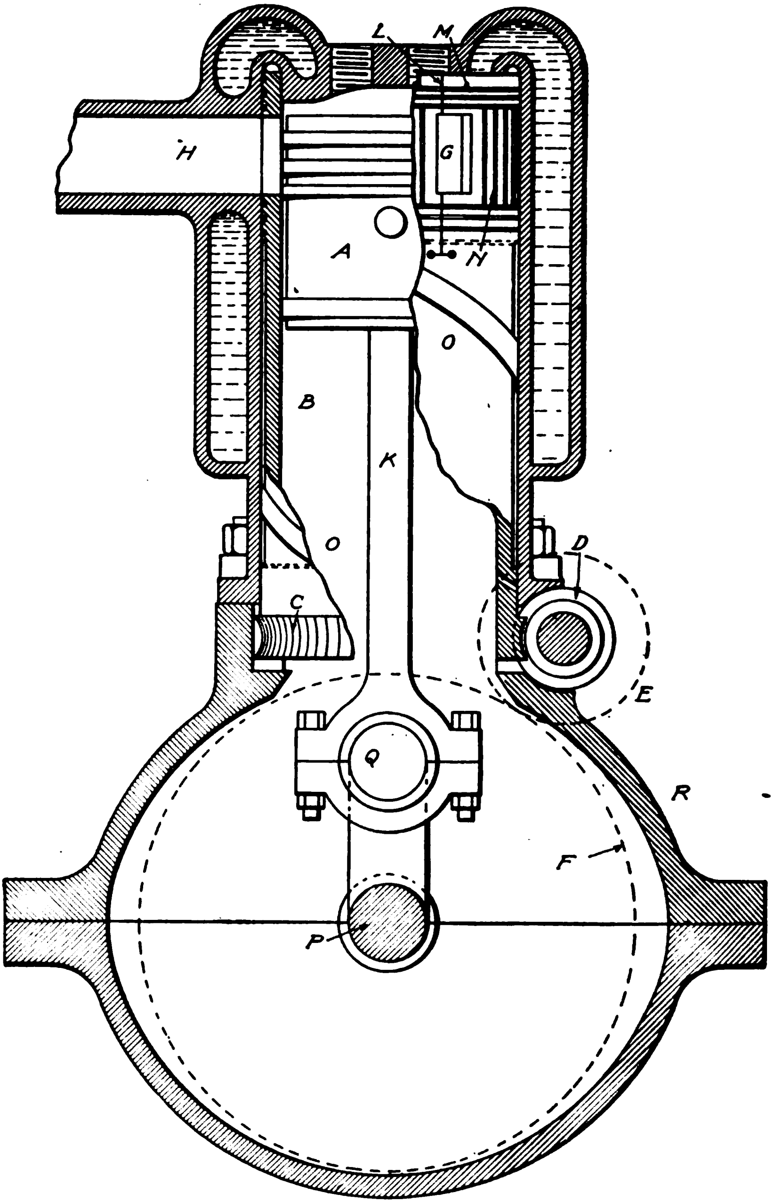


Fig. 103. Section through Ledru (French) Camless Engine
The Rotary Gear-Driven Sleeve Displaces All Cams

it and hence invisible in this figure, is a similar port for the inlet. As the crank shaft rotates, the side shaft carrying the worm is constrained to turn also. This turns the worm which rotates the worm wheel and with it, the sleeve. Thus, the openings in the sleeve are brought around to the proper openings in the cylinder, and the combustion chamber is supplied with fresh gas, and the burned gasse carried away at the correct time in the cycle of operations.

With a motor of this sort, the greatest question is that of lubrication. The manner in which it is effected in this case, is by means of the large wide spiral grooves shown at *O O*, and the smaller circular grooves at the upper end *M*. This problem is also rendered more easy of solution by the machining of the sleeve, as during this operation, much metal is cut away along the sides, so that the sleeve does not bear against the cylinder walls along its whole length, but only for a short length at the top and a still shorter length at the bottom.

The same result is accomplished in a slightly different manner by the use of a combination of eccentrics and levers, as is indicated in Fig. 104, showing the idea of a New York inventor, Osborn. This scheme places upon the usual cam gear an eccentric pin, upon which is located an eccentric rod or lever *A*. The latter is pivoted at its lower end to a pin *B*, which pin is a part of a sliding member *C*, carrying upon its upper part a piston rod *E*. This slide reciprocates, according to the impulse imparted to it by the eccentric *A*, being guided by the slides *D*, which are fixed to the side of the crank case.

Upon the upper end of the piston rod *E*, is fixed a piston *F*, and slidably mounted around the whole is another piston valve *J*. The former is always moved by the rod, while the latter is only moved upward by the collar at *I*, its downward motion being produced by a spring, not shown. *G* is the combustion chamber into which it is desired to lead the fuel mixture, and out of which the exhaust gases must afterwards be taken through the exhaust pipe *H*. *K* is the inlet pipe, *L L* are the inlet ports, and *M* is the exhaust port. Unfortunately, this drawing shows the piston at the top of its movement, which would be more clear were it at the bottom. On the down stroke of the inner piston, moved positively by the eccentric, the exhaust gases rush down and out. On the same stroke, the inflowing gas fills the passage around the outside of this, so that when the exhaust stroke is completed, and the piston has risen so as to uncover the lower edge of the port through the walls *O*, the

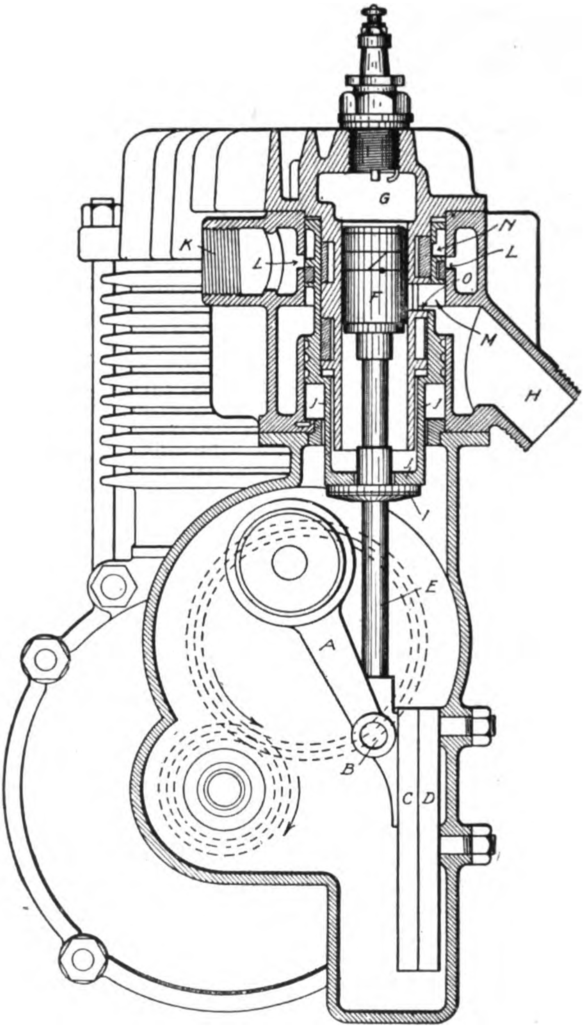


Fig. 104. Osborn Valve Motion without Cams

gases are free to rush in, impelled by the suction of the motor piston. In the meantime, the rising outside sleeve has covered the exhaust port *M*, so that none of the mixture may escape to the outside air.

Much publicity has been given of late to the product of a Chicago man, Knight by name. In this, a regular four-cylinder, four-cycle engine, the valves consist of a pair of concentric sleeves, openings in the two performing the requisite functions of valves in the proper order. These sleeves, as Fig. 105 shows, are actuated from a regular cam shaft—running at half the crank-shaft speed and driven by a silent chain—by means of a series of eccentrics and connecting rods. In the figure, *A* is the inner and longer sleeve carrying at its lower end the groove or projection *C*, around and into which the collar actuating the sleeve is fixed. This collar is attached to the eccentric rod *E*, which is driven by the eccentric shaft shown. The collar *D* performs a similar function for the outer sleeve *B*.

At the upper ends of both sleeves, slots *G* are cut through to serve as connection between the inside and the outside. These slots are so sized and located as to be brought into correct relations to one another and to the ports in the cylinder walls, exhaust at *H* and inlet at *I*, in the course of the stroke.

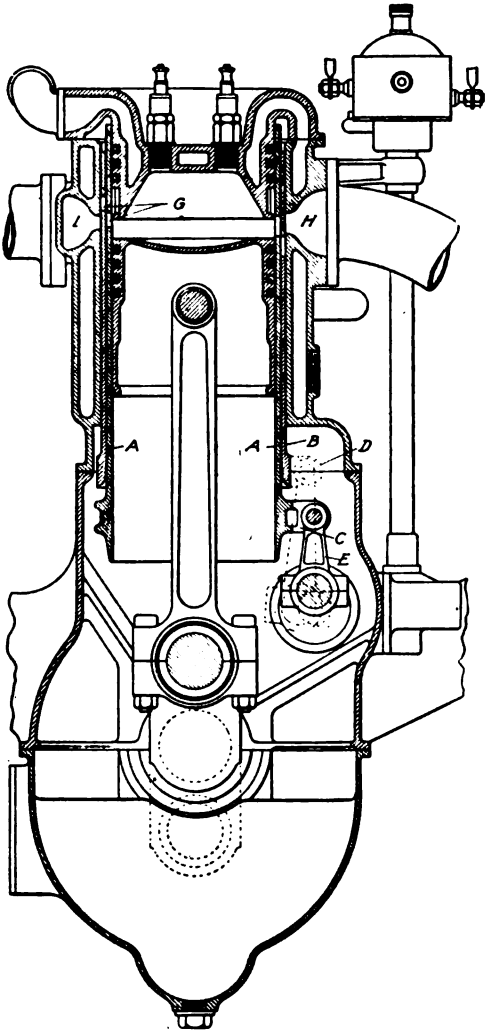


Fig. 105. Knight Engine. Eccentrics and Sleeves Replacing Cams and Valves

While at first thought, this engine might be considered as lacking in power from the fact that the sliding sleeves would eat up more power in internal friction than would otherwise be gained, the fact remains that a very severe and unusually thorough test of an engine of this type, made by the Royal Automobile Club of England, an unbiased body, proved that for its size, the power output was greater than many engines of the regulation type. Moreover, the amount of lubricating oil was small, just the contrary of what would be supposed.

This test was unusually severe and resulted as shown by Table III.

TABLE III

Royal Automobile Club's Committee Report on Knight Engine

Motor horse-power—R. A. C.		38.4	22.85
Bore and stroke		124 by 130	96 by 130
Minimum horse-power allowed		50.8	35.3
Speed on bench test		1200 R. P. M.	1400 R. P. M.
Car weight on track		3805 pounds	3332.5 pounds
Car weight on road		4085 pounds	3612.5 pounds
Duration bench test		134 hours 15 min.	132 hours 58 min.
Penalized stops		None	None
Non-penalized stops		Five—116 min.	Two—17 min.
Light load periods		19 minutes	41 minutes
Average horse-power		54.3	38.83
Final bench test		5 hours 15 min	5 hours 2 min.
Penalized stops		None	None
Light load periods		15 minutes	1 minute
Average horse-power		57.25	38.96
Mileage on track		1930.5	1914.1
Mileage on road		229	229
Total time on track		45 hours 32 min.	45 hours 42 min.
Average track speed		42.4 M. P. H.	41.8 M. P. H.
Fuel per brake horse-power per hour	First bench	.679 pt.	.739 pt.
	Test	.613 lb.	.668 lb.
	Final bench	.599 pt.	.749 pt.
	Test	.541 lb.	.677 lb.
Car miles per gallon	On track	20.57	22.44
	On road	19.48	19.48
Ton miles per gallon	On track	34.94	33.37
	On road	35.97	31.19

After the test was concluded, the sleeves, Fig. 106, were found to still show the original marks of the lathe tool. This proved conclusively that the principle of this type was right, for the tests were equivalent to an ordinary season's running.

In Fig. 106, the sleeves are marked with the same letters as in Fig. 105. *A* being the inner and noticeably longer one, while *B* is the outer and shorter one. At *C* and *D*, the attaching collars and the pins on which the connecting rods are attached may be seen, while at *G G* are shown the slots which serve as valve ports. *J J* are oil grooves for the purpose of carrying oil around the sleeves, and thus rendering their movement up and down easy.

The inventor of this last-named form of engine had it in mind to bring out an engine that would be economical of fuel and in this way reduce the cost of upkeep. As to its fuel economy, only time can tell that, but the design is such as to require a regular carbureter and fuel vaporizing system just as other engines do. This fuel vaporization problem is one which has agitated automobile men ever since the time of Benz, Daimler, and other pioneers. Their first problem was one of carburetion, and today manufacturers argue over the best type and form of mechanism to do the same work, some stating that it is better to buy from a carbureter specialist, while an equal number maintain that it is better to make it themselves and after their own ideas.

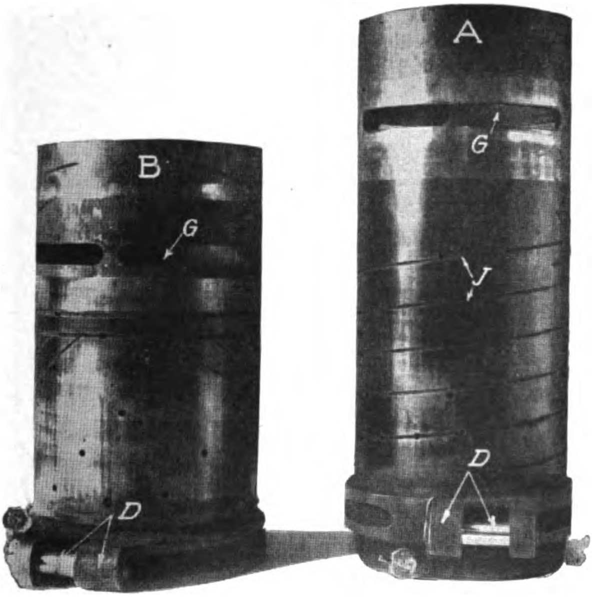


Fig. 106. Sleeves Which Replaced Valves on Knight Engine. After 137-Hour Bench Test and 2,200 Miles on the Road

CARBURETERS

Classified according to structure, operation, and principle, all fuel vaporizing devices may be divided into three main classes, which are as follows:

1. The surface carbureter.
2. The ebullition or filtering carbureter.
3. The float feed or spraying carbureter.

As most of the modern devices come in the last-named class, it will be sufficient to speak of the other two briefly. The early devices were mainly of the surface type, in which the air passed over the surface of a body of fuel, picking up some of it, Fig. 107. Another early form circulated the air around gauze, wicking, or other surface saturated with fuel, Fig. 108. Benz used a vaporizing device of this sort in his earlier machines. Both of these methods are in use today, but in combination, and not as the sole source of gas.

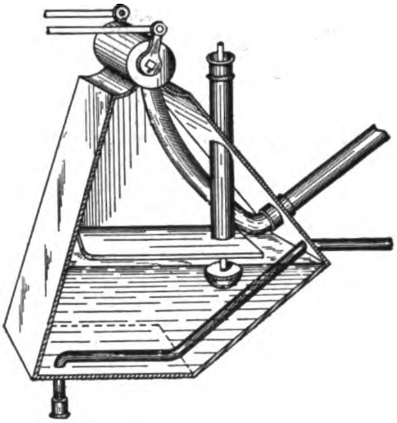


Fig. 107. Original De Dion Surface Carbureter

Another very old device is called the *ebullition* or *filtering carbureter.* In this, air was forced through a body of liquid, which entered at the bottom and in its passage to the top absorbed small particles of the fuel. Daimler began with this style, but later abandoned it in favor of the Maybach float-feed spraying arrangement, which was the prototype of the form now in prevailing use. The filtering scheme is, however, still used.

A fourth, and the most common, basis of operation, is the *spraying* or *atomizing* of the liquid through a very fine nozzle, the vapor being picked up by the inrushing air. The first of this type, the *Maybach,* Fig. 109, was remarkable, in comparison with its modern successor, principally for its simplicity. There was a float, controlled by the amount of liquid, and a nozzle. The air entered around the nozzle and, mixing with the fine spray of fuel in a chamber directly above the cylinder, was drawn from there into the combustion chamber.

Although simple, it was also crude and the heat from the cylinder doubtless had much to do with its success. The nozzle was large, as such sizes go today, but in spite of all these defects it worked, and worked better than anything that preceded it.

Defects in the Original Are Not Found in Modern Types. The original carbureter had no adjustment; the opening in the casting measured the amount of air; the size of the nozzle measured the amount of the fuel and the fineness of the spray. There was no means of regrinding the float valve, and thus no way of assuring an even and continuous flow of fuel. The modern adjuncts of the original Maybach device consist of remedies for these defects, and, in addition, a proper means of balancing and adjusting the float.

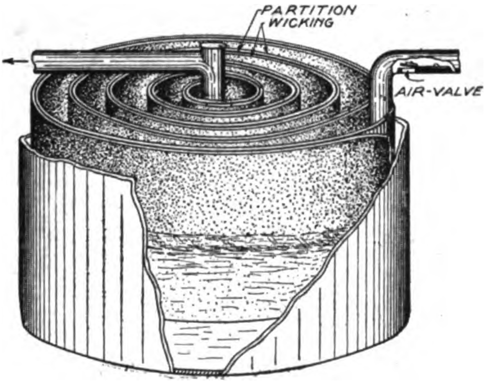


Fig. 108. Wick Vaporizing Device

To pick out a modern carbureter at random, take the one shown in Fig. 110. Like its ancestor, this has a gasoline chamber into which the fuel is admitted by the action of a float, first passing through a strainer. From the float chamber the liquid passes up to and through the spraying nozzle. The weight of the float is so calculated that the level in the final nozzle is just 1 millimeter (0.04 inch) below the top. This insures that there will always be fuel there for the air suction to draw off. As the chemical action of changing a substance from a liquid to a gas is usually accompanied by the absorption of heat it is

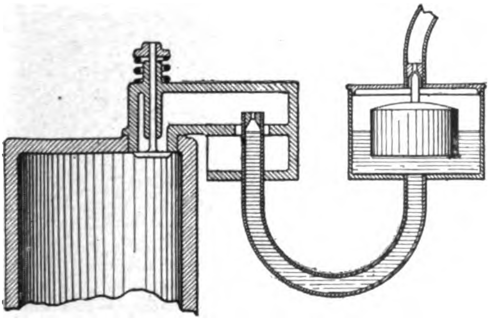


Fig. 109. Original Maybach Carbureter

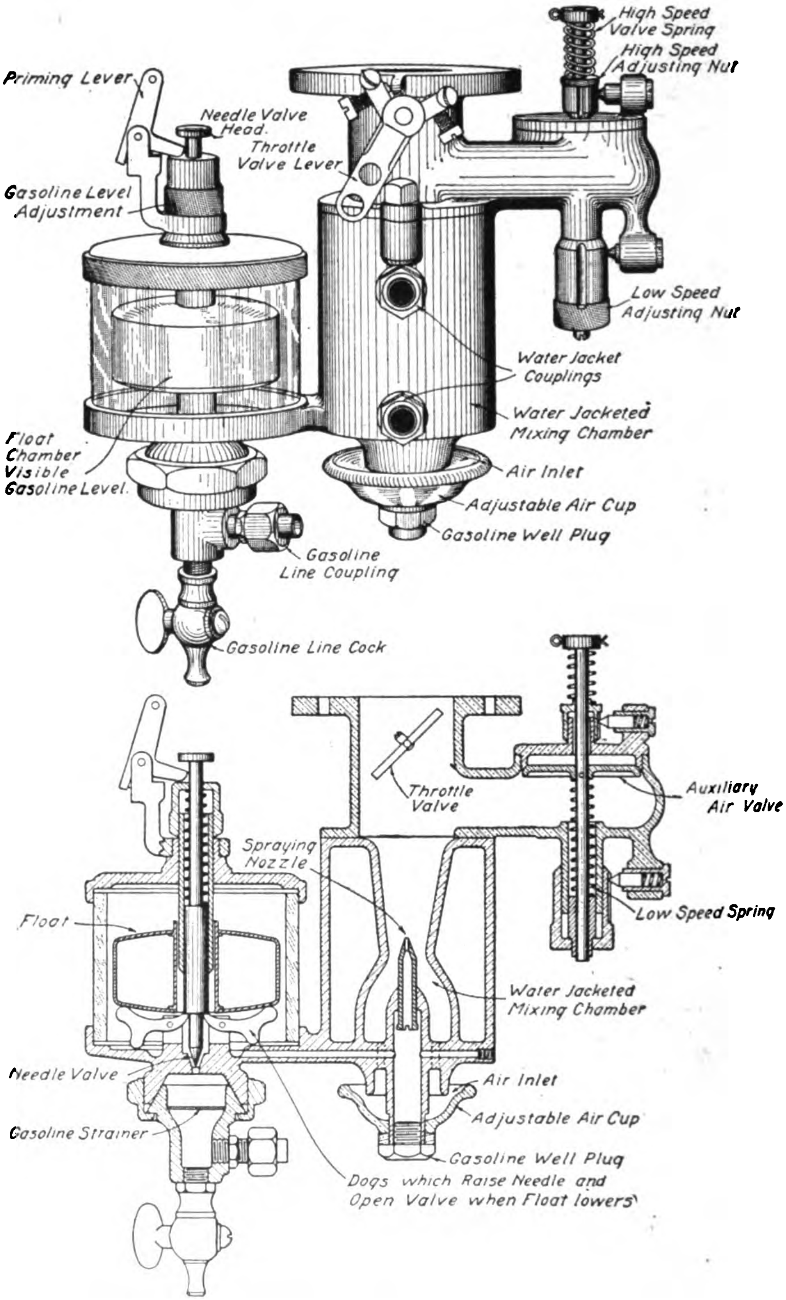


Fig. 110. American Carbureter with Venturi Shaped Mixing Chamber
Stromberg Motor Devices Company, Chicago, Ill.

advisable to supply a reasonable proportion of this and thus assist the change of form. In the older Maybach, this was inadvertently done by placing the whole apparatus in close contact with the hot cylinder. In the modern carbureter, placed some distance from the heated portions of the engine, this additional heat is supplied by the jacket water. An alternate scheme is to preheat the air supply by a special pipe from the exhaust manifold.

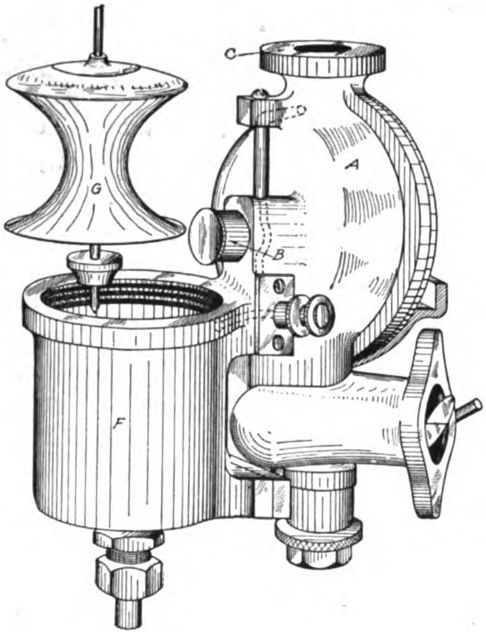


Fig. 111. Gillett-Lehmann Carbureter.

From this mixing chamber the mixture of air and gasoline vapor passes upward into a secondary mixing chamber. This communicates with the inlet pipe through the medium of the throttle valve. Into the latter chamber, the auxiliary air supply (when used) has access through the auxiliary air valve. This comes into action on very high speeds when the engine is pulling very strongly, for which the proportion of gasoline to air is liable to be too large, so the auxiliary opens, admits more air, and thus dilutes the mixture.

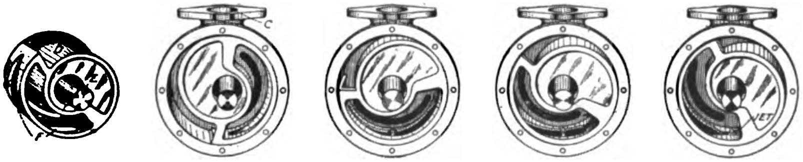


Fig. 112. Gillett-Lehmann Throttle

Another form of carbureter which embodies many novel ideas is illustrated in Fig. 111 and shown in detail in Fig. 112. In the former, *A* is the casing of the throttle valve, which is the principal feature of this device. *B* is the inner end of the throttle valve shaft, while *C* is the flanged pipe for attachment to the inlet to engine. *F* is the float chamber, not different from the ordinary one, while within it, the float *G*, hollow metal, works up and down just as do hundreds of others.

In Fig. 112, however, the throttle valve is shown in its casing, one side being cut away for the sake of clearness. In this *D* is the throttle and *E* the end of the shaft, while *C* indicates the same flanged connection as before. The throttle *D* has a spiral exterior, and being set into a circular hole, of which just the tip of the spiral is a close fit, there is always an opening around the outside of it and between it and the casing. The air enters at the center of the bottom, around the gasoline spray nozzle. In one side of the throttle is cut a slot of varying width, the ends being straight for a very short distance and of a width just equal to the size of the gasoline nozzle. In the extreme left-hand view the throttle is removed from the casing, showing the slot *F;* while in the second view, the throttle is placed in the casing, but so turned that the passage to the engine is cut off. Air may enter as well as gasoline, the nozzle projecting through the small end of the slot at the bottom.

With a quarter rotation to the right, as shown in the third view, a slight opening is formed at the top so that the mixture may be drawn into the cylinders in small quantities, the nozzle being entirely opened and uncovered. In the fourth view, an additional turn has brought the spiral exterior of the throttle valve around to such a point as to leave the maximum possible opening between itself and the casing at the top. This, then, is the full opening, both gasoline and air openings being also wide open. Turning a little further leaves the outlet about as large as before, but restricts the gasoline spray, leaving the air unchanged. This latter is the position which would be assumed for full speed on a level road, the over-rich mixture being detrimental in this case.

Throttle Valves in General. Whatever the character of the mixture in the carbureter, it is admitted to the cylinder by the throttle valve, which may take the form known as the *butterfly.* This is a flat piece of sheet metal, preferably brass, attached to a suitable shaft with an operating lever on the external end. Not all throttles,

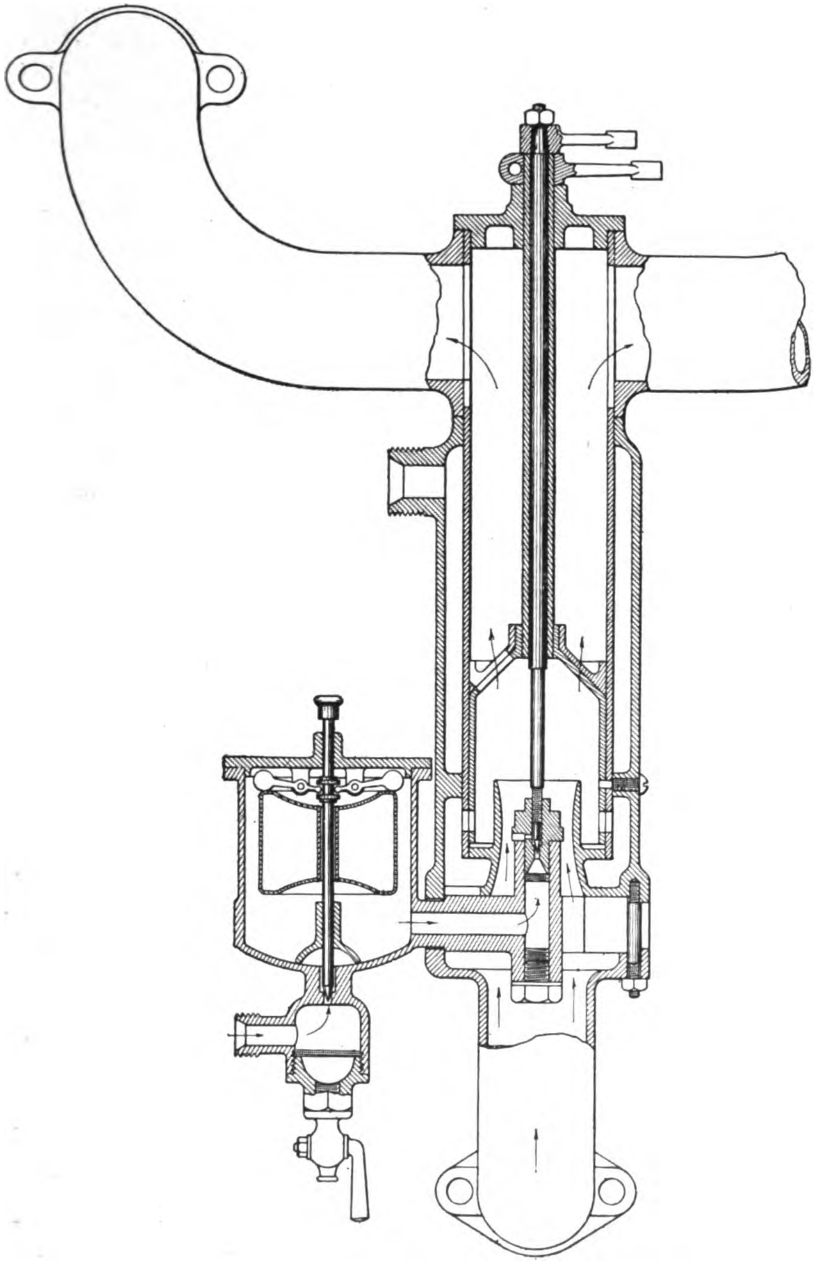


Fig. 113. Carbureter and Inlet Pipe of Gaggenau (German) Commercial Vehicles

however, are of the butterfly type, there being fully as many of the *piston* type. This consists of a cylindrical ring or shell of metal, which is free to slide in a corresponding cylindrical chamber. In the walls of the latter are a number of apertures or ports which the longitudinal movement of the piston either uncovers or covers as the case may be. Sometimes to facilitate this action, the sides of the piston are grooved or notched, but this does not alter the principle of sliding a cylinder within another cylinder to cover or uncover certain ports in the cylinder walls. This form of throttle is used and advocated by such prominent firms as Napier, Panhard, Krebs, and other equally famous constructors.

Floats. Another feature of the earlier forms of carbureters, which was soon found to be in need of a change, was the arrangement of the float. In Maybach's original vaporizer, there was no means of balancing the float; consequently, there was no way of preventing wrenching and breaking of the needle valve spindle. As this disarranged the gasoline supply, it was very important and received early attention. In addition, there was the necessity for reliable devices to regulate the supply of air and gasoline spray from the nozzle, either by original adjustment or by means of a governor or else effecting by hand a constant variation to meet constantly varying conditions of engine demands.

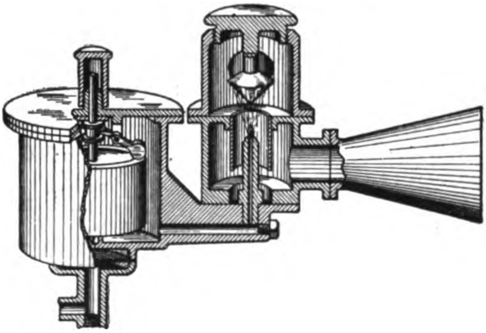


Fig. 114. Phoenix-Daimler (French) Conical Spray Interceptor

These additions to the original form caused some trouble. The ordinary way of managing the balancing of the float, while it may be the cause of trouble at times, is a very simple one. The float is of exceeding lightness, whether made of cork or metal. With the in-flow of gasoline in liquid form this float rises and in so doing it strikes against a pair of small pivoted levers near the top of the float chamber, Fig. 113; the other ends of both of these rest upon a form of shifting collar on the needle valve stem. So, when the float rises above a certain level, it automatically shuts off the flow of gasoline, by pressing against the pivoted levers, which, in turn, act against the stem and press it down until the flow is cut off. The float will stay up until the suction of the engine has lowered the gasoline level so that the dropping of the float releases the levers which raise the needle valve off of its seat. The gasoline flow is thus automatically regulated by this balanced float arrangement.

Adjustment of Air Supply and Gasoline. Probably no one detail of the whole list of carbureter parts has caused and still does cause more difference of opinion than the source of and adjustment of the air supply, and its companion, the adjustment of the gasoline spray. The latter drew attention long before the former did; in fact, the former is more of a modern appliance. The fuel spray was investigated long ago; thus, in the Phoenix-Daimler, Fig. 114, the gasoline spray had no adjustment, but the size and location of the level of the nozzle were fixed. The spray itself, however, received special treatment, being projected against a conical spray deflector, which served to break up the column into finer and more diffused particles. In this way, greater vaporizing action was gained.

Longuemare, the famous French carbureter expert, had a different method, Fig. 115, which consisted in dividing the spray, before the air struck it, into a circular column of finely divided particles. These were then easily picked up by the incoming air, which in its upward passage was further diluted by the addition of more air. The latter was added at a point where the carbureted gas was obliged to turn a right angle, at which any remaining particles of pure gas would have been thrown off by centrifugal force. The down-coming stream of extra air met these particles and by carrying them along prevented what would otherwise have been a waste of fuel. This carbureter has long been noted for its fuel economy.

In Fig. 115, *A* is the float chamber, containing the hollow metal float *B*. Gasoline enters from below, *I* being the gasoline pipe connection, *J* the drain cock, and *H* the gasoline chamber with the needle valve at the top. At the top of the float chamber the small lever for priming may be seen at *E*, while *C* is the removable cover, with the bushing *D* covering the end of the needle valve shaft. The gasoline flows across the horizontal passage to the vertical one, in which the spray nozzle is located. This spray is formed by the fuel

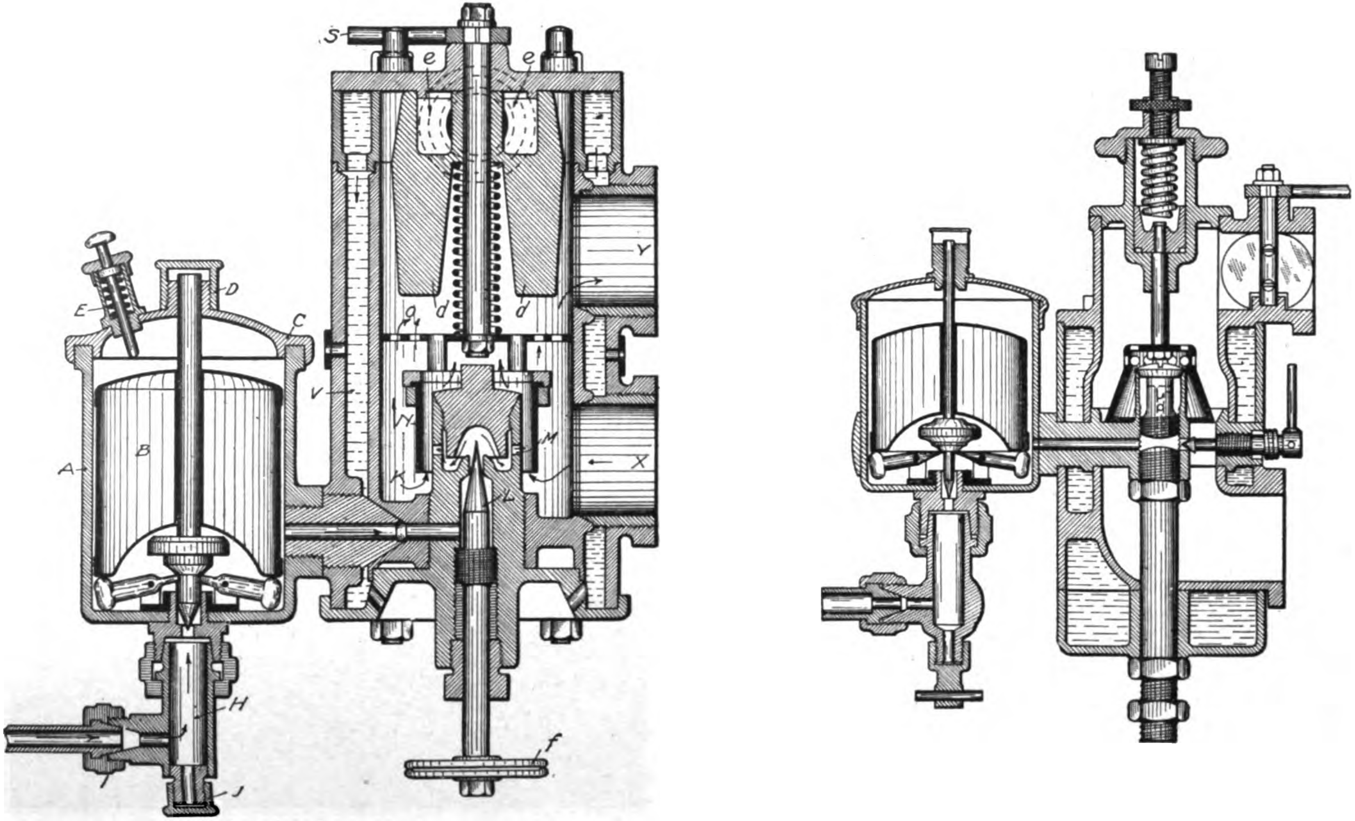


Fig. 113. Longuemare (French). Arranged for Alcohol, and King (American License). Arranged for Kerosene

passing through the small orifice formed between the restricted upper part of the vertical passage and the point of the *needle L.* Just above this, so that the spray impinges upon it, is placed an inverted cone, which deflects the gasoline spray down again and outward through short horizontal apertures *M.* Around these openings is placed a hollow cylindrical shell *N* open at the top and with holes *K* in the bottom. The air rushes in through these latter, and picking up the gasoline spray, passes along out of the top of the cylinder, being augmented outside by additional air rising around the outside of the cylindrical shell *N.* The mixture then passes upward through the diaphragm filled with holes *O*, and thence into the pipe to the cylinders *Y.* *X* is the air inlet. The auxiliary air enters at the top, its entrance being controlled by the balance established between the weight with two arms *d d* and the central spring. The two small openings *e e* indicate the location of the auxiliary air pipe, while *v* is the water jacket—at the time this particular model was brought out, however, it was used as a hot-air jacket, instead of the more modern hot water. The lever *S* controls the amount of mixture admitted, while the hand wheel *f* governs the adjustment of the needle *L.* In the right-hand corner of Fig. 115, the King carbureter is shown. This was an American copy of the Longuemare, but made under license.

So, too, this same make is noted for being among the first to use a water jacket around the vaporizing chamber. The conversion of a liquid into a gas is an endothermic reaction and requires heat for its completion. If this be not supplied by external means, it will be extracted from surrounding objects. This accounts for the frost which gathers on the outside of the mixing chamber of carbureters which do not have a water jacket or other source of heat supply. The heat is abstracted from the air so rapidly that the moisture in the air is frozen, appearing as frost on the outside of the carbureter.

As for an auxiliary air valve, this has always been a source of discussion, its opponents claiming that it means extra parts, and therefore more adjustments and more sources of trouble; while those favoring it say that without some additional means of this sort for diluting the mixture at high speeds, it is impossible to run the engine fast, as high speed will then mean an over-rich charge. Be that as it may, the fact remains that the weight of opinion lies with the auxiliary valve.

Usual Form of Auxiliary Air Inlet Valve. The auxiliary air inlet usually consists of a simple valve opening inward, held in its place by a spring of a certain known tension. The strength of the spring is carefully determined so that at the proper moment, when the motor requires more air in proportion to the amount of gasoline used, the valve will open just enough to allow the required amount of air to enter. It will be seen that the time and the amount of opening will be controlled by the speed of the engine, *i. e.*, by the amount of suction produced by the movement of the piston in the cylinder. Of course, as the engine speeds up, there is a greater piston displacement to be filled per minute, and therefore it is necessary to supply a greater amount of mixture. Upon changing speed suddenly from, say, 500 revolutions to 900 or 1,000, the carbureter not having this device will *not* give a uniform mixture immediately, and, in fact, it might require a new adjustment of the gasoline flow in order to supply the right amount of fuel. What the auxiliary air inlet actually does, then, is to automatically control above a certain point the amount of air admitted, thereby always maintaining a homogeneous mixture. In order to prevent any chattering of the valve or rapid changes in the air supply, a *diaphragm* or *dashpot* is sometimes used in connection with the valve. Figs. 116 and 117 show types where the former method is used. Fig. 118 is an example of the latter.

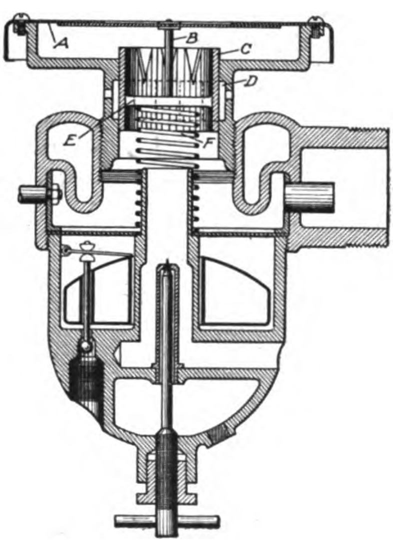


Fig. 116. Diaphragm to Control Auxiliary Air Admission

In Fig. 116, instead of using a regular valve, a piston valve is introduced which, however, accomplishes the same result in a slightly different way. This carbureter and its action will be rendered more clear by a little explanation. Referring to Fig. 116, the diaphragm *A* is mounted upon the top of the stem *B*, which carries, further down, the piston throttle *C*. This is open at the top end, but near the bottom has a partition *E* across it. The top edge of the throttle has notches cut in it of triangular shape. When the motor demands are such as to cause a partial vacuum in the center of the carbureter, the flexible metal diaphragm will give a little, allowing the piston throttle to come down slightly. This puts the lower ends of the notches into communication with the annular spaces *D* in the walls, so that air may enter at the top, pass through the notches, into the annular spaces, into the mixing chamber, and thence to the cylinders with the mixture. This action is resisted and restricted by the spring *F*.

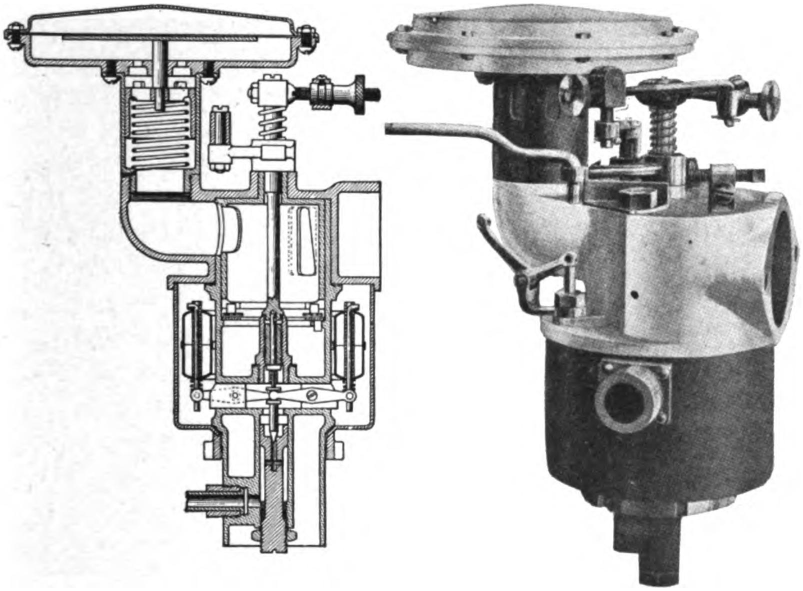


Fig. 117. Section and View of Carbureter Showing Diaphragm
Chadwick Engineering Works, Pottstown, Pa.

In Fig. 118, *B* is a short piston formed on the lower end of the throttle valve stem *C*. This piston works up and down with the motion of the throttle, its action being opposed by the immobility of the liquid placed in the dashpot *A*. This quality of liquids prevents sudden changes in the fuel supply to the engine, which changes are not desirable—a sudden increase of mixture, for instance, causing racing, while an equally sudden decrease will stall the engine.

To obviate any difficulties which might arise from the use of several different liquids, the gasoline itself is used as the liquid for the dashpot, the by-pass at the right leading it into the dashpot. In all other particulars the carbureter follows standard practice.

An ingenious method adopted by the makers of the G. & A. (short for Grouvelle & Arquembourg) carbureter avoids the principal argument against the auxiliary valve. In this device, shown in Fig. 119, a row of steel balls *A A* are set into as many holes in the ball casing *B*, which communicate with the outer air on the lower side. The balls are free to rise vertically and are of varying sizes from an eighth inch to about three-eighths inch in diameter. As the engine speeds up and draws on the mixture chamber, the lighter and smaller balls are lifted off of their seats, admitting a small amount of air. With greater speed and consequently greater draft, larger and larger sized balls are lifted, admitting more and more air. There are no springs to bother with and no adjustments, the number and size of the balls, fixed by the manufacturer, being equivalent to this. The expense of making the carbureter may be lessened by incorporating in it the inlet pipe. This is frequently done in European cars, as shown by the German carbureter Wildi, Fig. 120. This form uses the piston throttle but the movement is in a vertical direction, contrary to that of all others shown. This is due in part to its being an integral part of the inlet pipe.

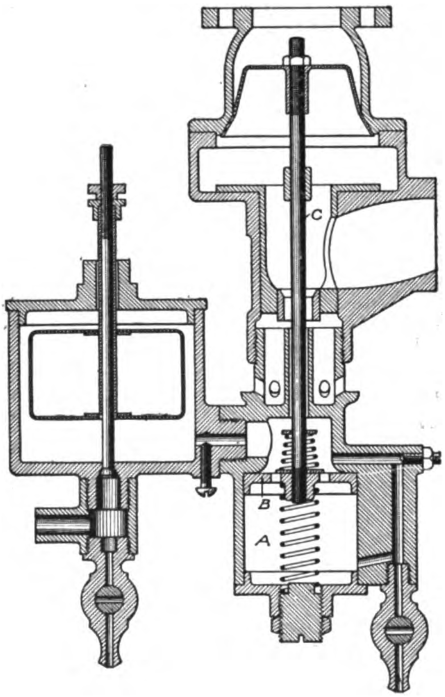


Fig. 118. Dashpot to Regulate Air Supply

This throttle valve *A* is located on the lower end of the throttle stem *B*, to which is connected the operating levers. The piston throttle

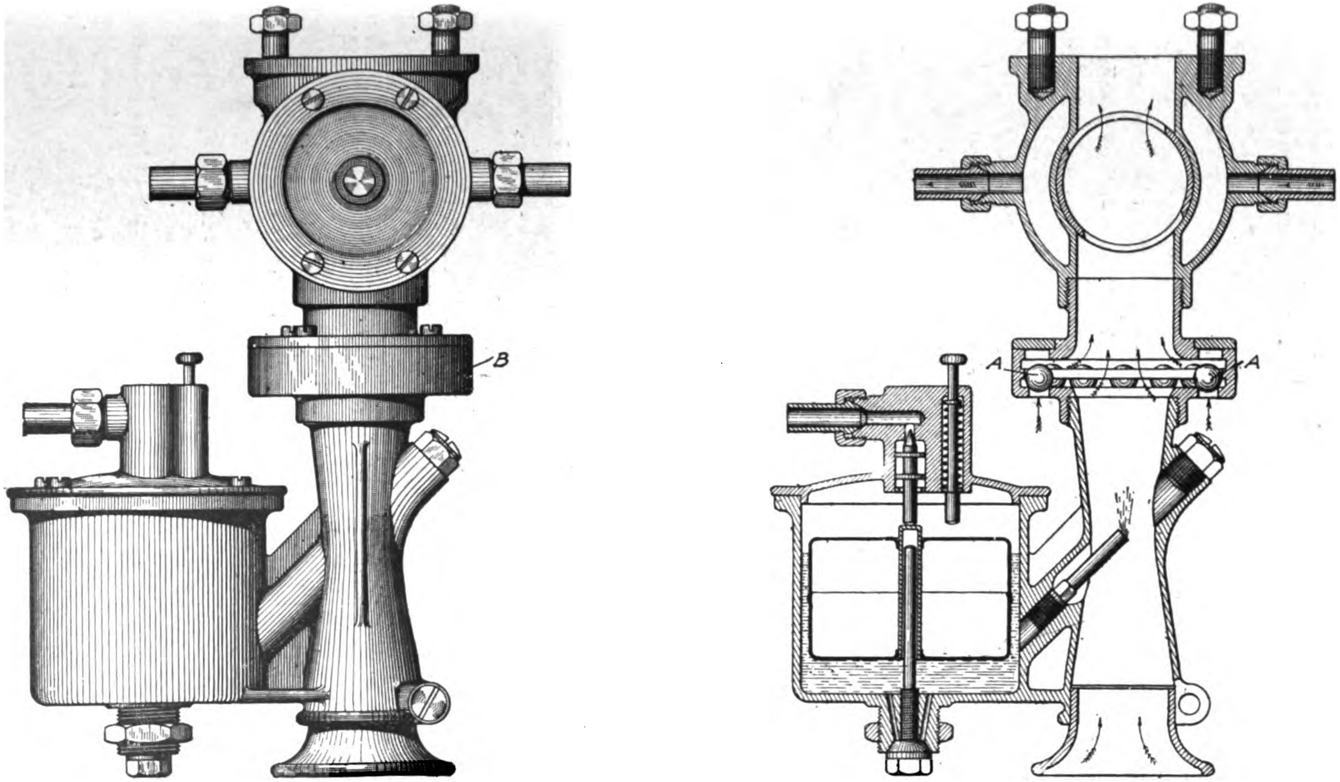


Fig. 119. **Elevation and Section of Original Venturi Tube Carbureter**
Grouvelle et Arquembourg, Paris.

A has a row of large holes near the top, through which the mixture passes when the throttle is raised sufficiently to permit this. A still further upward movement uncovers additional air holes through the exterior casing *C* of the carbureter. The remaining actions of the device either are self-evident or follow standard lines. The heating of the gasoline previous to vaporization by means of the circulation of the exhaust gases around the fuel chamber at the bottom, will be noticed.

Of course, like every other part of the action of a carbureter, the spraying action and the shape or size of the chamber in which it takes place, have been the subject of much debate. Originally, the chamber took any convenient shape and varied all the way from a perfectly plain cylindrical shape to an equally perfect square, with all of the possible variations in between. About two years ago, however, scientists began to look into the vaporizing and equally important measuring action of carbureters, with the result that a new shape came into use, which was based upon a scientific principle.

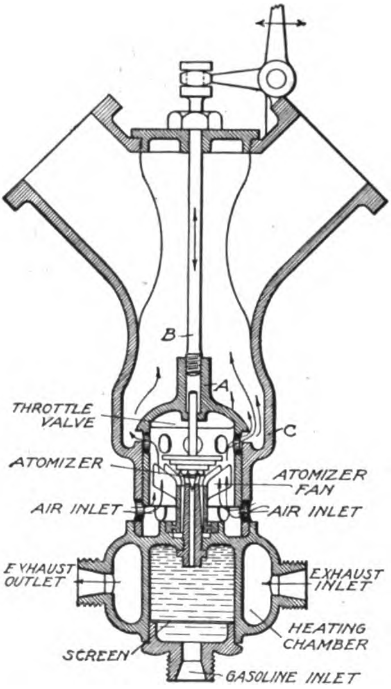


Fig. 120. Wildi (German) Carbureter

This is the principle of the Venturi meter used for measuring the flow of water, and from its use, the tube, or chamber, having this shape has come to be known as a *Venturi tube.* In shape, this consists of two cone-shaped tubes diverging in opposite directions from a common point, which in the water meter is the *point of measurement* and in the carbureter is the *point of location* of the spray nozzle. The principle is that if these two frustums of cones are of the proper shape, *i. e.,* include the proper angle, and are correctly set with relation to one another, the flow of air and gas will be in correct proportion to each other at *all speeds,* assuming first that the air enters at the bottom of the tube having the greater angle.

Venturi Tube Type. As bearing out the principle of this type of vaporizing chamber, it might be said that the majority of carbureters in use today have incorporated it in one form or another, as seen in Figs. 121, 124, 126, 127, and 130. Many make the upper tube conical for a very short distance, beyond which it assumes a cylindrical form. In the true Venturi shape, the usual angle at the bottom is 30 degrees, while that at the top is 5 degrees. In water meters the contracted area is made one-ninth that of the pipe. This same relation, although not exact, holds in the case of the carbureter. Since the area varies as the square of the diameter, this is equivalent to saying that the diameter of the contracted pipe should be one-third that of the full-sized pipe.

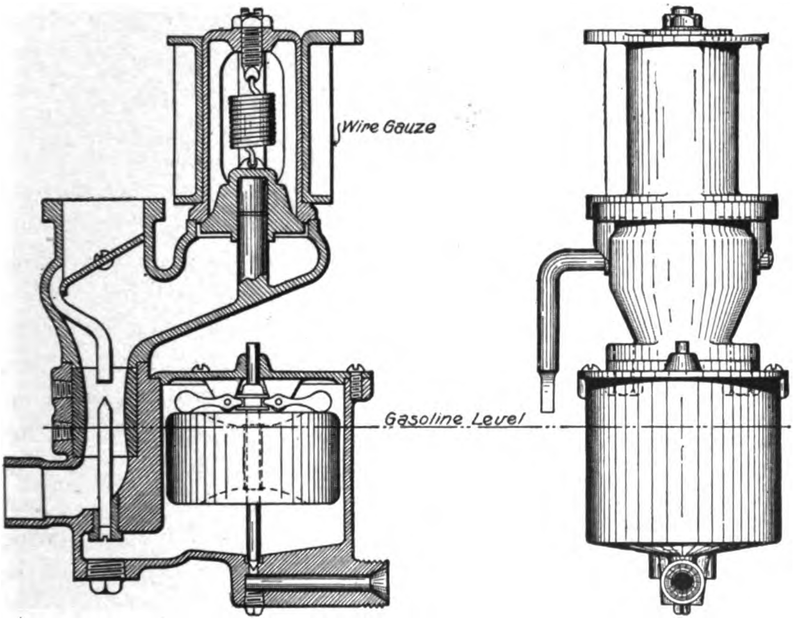


Fig. 121. Oakland Carbureter

Examples from Up-to-Date Practice. As having much bearing upon the subject and being more to the point than random theorizing, look at some examples of modern carbureter practice as shown in the section of the De Dion carbureter, Figs. 122 and 123. These illustrations show a number of interesting small points, close attention to which have made the French the foremost automobile constructors.

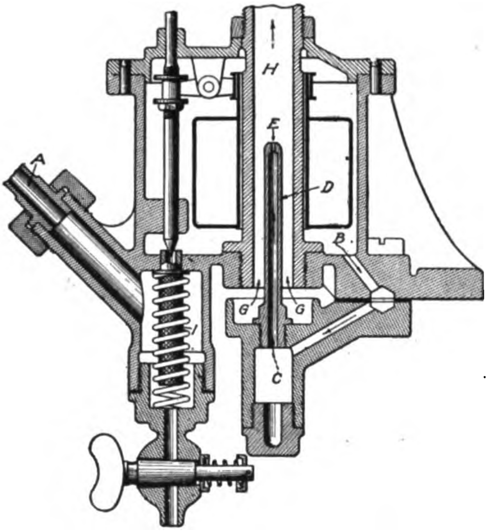


Fig. 122. De Dion Carbureter Showing Strainer and Float Chamber

Of these two views, Fig. 122 shows the carbureter, while Fig. 123 shows the throttle chamber located higher up in the inlet pipe, and very close to the cylinders. In Fig. 122, the gasoline enters through the pipe *A*, passes through the gauze strainer *I*, through the needle valve into the float chamber, thence, through *B* into the pool *C*. From this a vertical pipe *D* rises to the spray nozzle *E*. Air enters at the base through the holes *G*, passing upward around the standpipe *D*, vaporizing the liquid at the top of the latter, and passing on through the pipe *H* to the engine. Before it can do this, however, it must pass through the throttle, shown in Fig. 123. In this, *H* is the mixture pipe as before, this reaching a throttle valve *J* of the piston type, in the walls of the open end of which are holes *K* through which the mixture enters. When withdrawn sufficiently to the left, the end of the piston clears the edge of the mixture pipe, so that the mixture may then pass directly into it instead of passing through the holes. *L* is the connection to the cylinders through which all gas mixture ultimately passes.

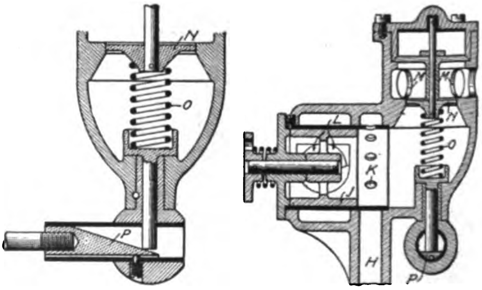


Fig. 123. Details of De Dion Throttle and Spring Tension Adjuster

In this chamber more air is added. This enters by the ports *M*, and through the valve *N*. The action of the latter is controlled by the spring *O*, which may be adjusted to any desired tension by means of the movable slide *P*. Since this has a tapered end, moving it in raises the stem, compresses the spring, and renders the auxiliary air valve more difficult to open. Consequently less air may enter. Drawing the wedge-shaped end outward has just the opposite effect.

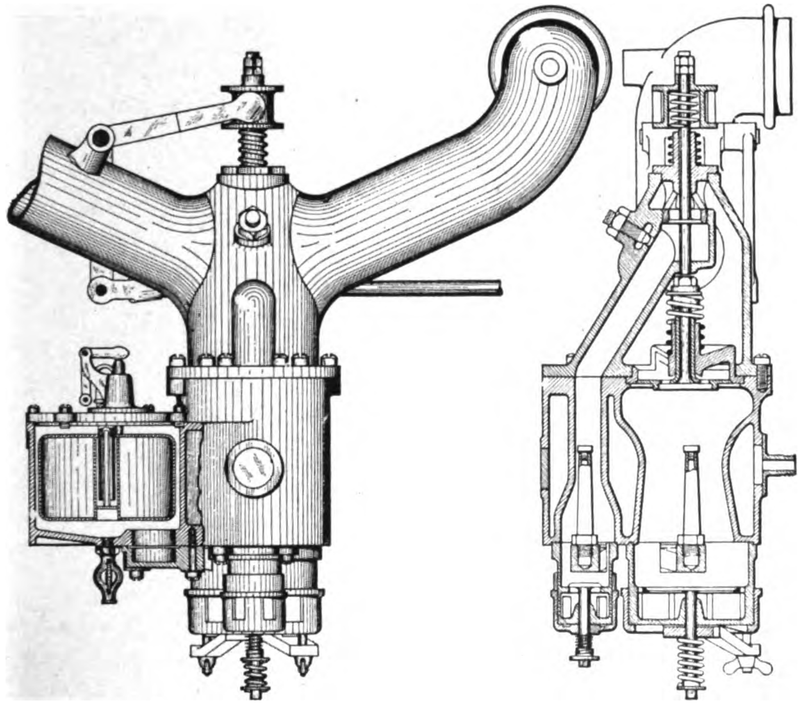
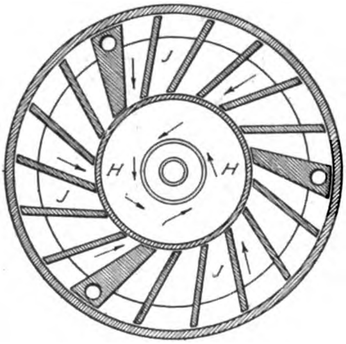


Fig. 124. Stearn's Two-Jet Carbureter

On the other hand, this country may lay claim to much ingenuity in working out desired ends. Thus, the carbureter in Fig. 125, a Detroit product, shows one attempt to perfect the vaporizing action of the air passing over the liquid fuel. This is done by making the passages through which the fuel passes upward, into a series of radial chambers, large in number and each one small in size. Air enters these from below and through the large ratio of air surface to fuel surface, the vaporizing effect is very good.

Gasoline enters at *A*, passes up into the float chamber *B*, thence through the passage *C*, into the standpipe *E*. Air enters at *G* rising around the standpipe and vaporizing the gasoline spray at the chamber *H*, above the spray nozzle *F*. Additional air enters at *I* passing through a series of radial vanes to the common center, the chamber *H*. From there the carbureted air passes through the pipe *K* to the cylinders. *L* is the adjustment for the needle valve *F*.



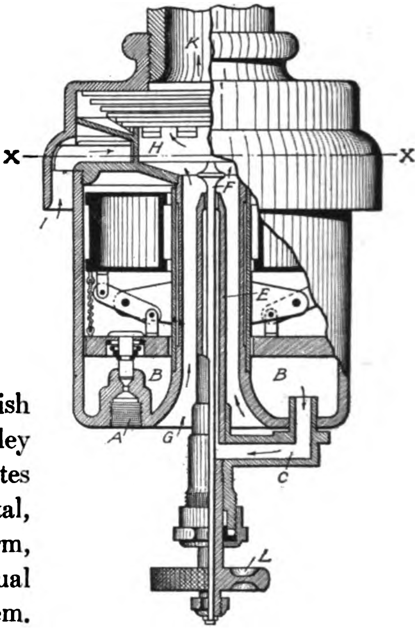


Fig. 125. Watts—Detroit Carbureter Left-hand Figure—Section Through *XX*.

One of the foremost English firms, the makers of the Siddeley car, have been steadfast advocates of the two-cylinder, horizontal, opposed engine. For this form, they have developed an unusual and very efficient carburetion system. This, as shown by Figs. 128 and 129, differs from the ordinary case in having a peculiarly shaped auxiliary air valve, and in the method of operating this and the vertical piston throttle valve.

To explain the operation with clarity, Fig. 128 and Fig. 129 must be considered together, as the latter is but the end of the vaporization system, while the former is the starting point of it. Gasoline from the tank enters at *A*, passes through the usual float chamber *B* into the standpipe *C*. Air enters at *D*, vaporizing the gasoline in the chamber *E*. The upper end of this, Fig. 129, tapers down to a small point, while the additional air enters it from above through the flat-seated valve *G*. The two are mixed in the chamber *F*, and thence pass through the throttle valve. This consists of two parts, the outer, *H*, being a *rotary* piston, operated for normal running by the lever *J*. Within this piston, however, is a sliding piston throttle *L*, which is operated by the additional lever *K*. The two in combination allow many and varied combinations of rich and lean mixtures to enter the inlet pipe *II*, and through it, to reach the cylinders of the engine.

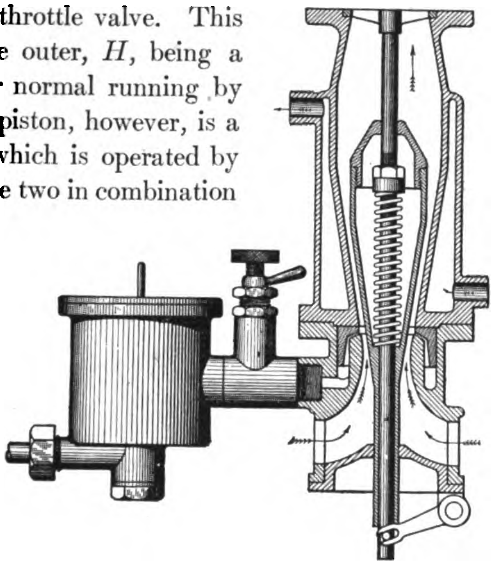


Fig. 126. Decauville (French) Carbureter Using Tapered Mixing Chamber

Not to be outdone by other nations are the Germans and the Swiss. As an example of the work of the latter, none would be more appropriate than that of the great constructor, Saurer, of Arbon, the designer of the Saurer and Safir trucks and pleasure cars. His carbureter design, known as the *Economy*, is shown in Fig. 131. The peculiarity lies in the two standpipes *A* and *B*, one of which may be cut off by the action of the flap throttle valve *C*. This latter is operated by the demands of the motor, consequently when the need for fuel is greatest, it stands vertically so that both fuel standpipes or nozzles are supplying fuel.

As shown in the figure, but one standpipe *A* is working, but as soon as the motor's demands

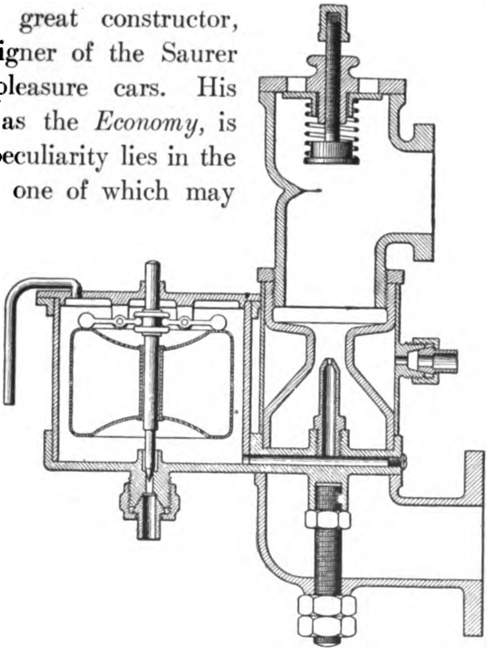


Fig. 127. Argyll (Scotch) Carbureter with Liberal Air Passages

increase, the suction will draw the flap throttle valve *C* out of its inclined position, and then standpipe *B* will begin to furnish gasoline to the vaporizing chamber in addition to standpipe *A*. When the demand is greatest, both nozzles are supplying the full amount of gasoline, and the flap is standing vertically. Its action is partially restricted by a wedge attached to the throttle valve stem.

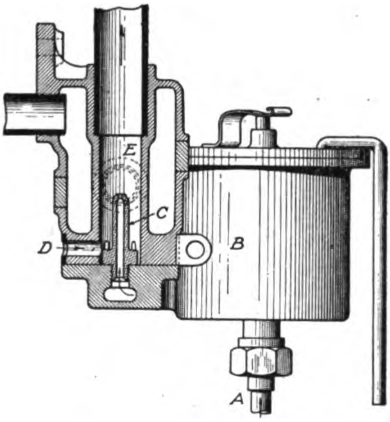


Fig. 128. Section Through Siddeley (English) Carbureter

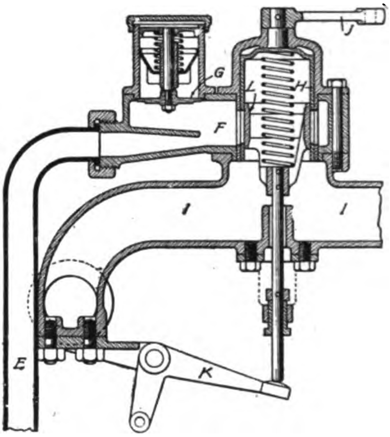


Fig. 129. Siddeley Mixing Chamber and Inlet Pipe

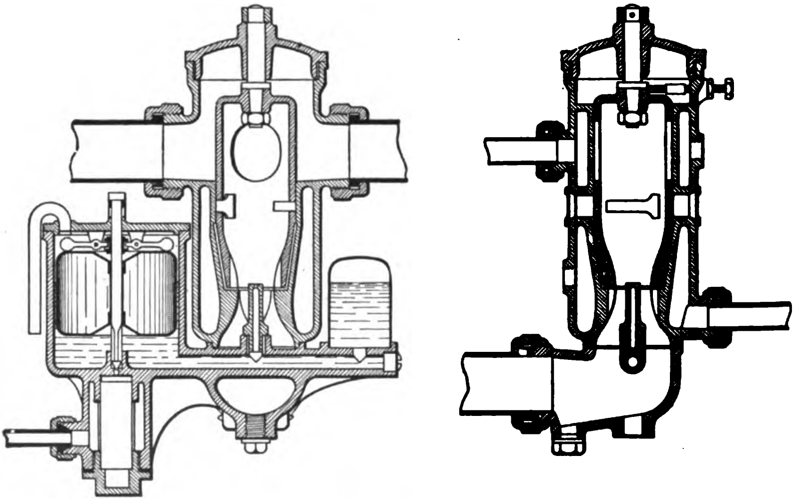


Fig. 130. Up-to-Date Daimler Carbureter, Shown in Two Sections
Daimler Actiengesellschaft, Unterturkheim, Germany.

No better type of German practice than the Benz could be selected. The carbureter from this car is shown in Fig. 132, in which the early connections of Maybach may be clearly traced. This is apparent in the rotary piston throttle, the shape and action of the float, the hand regulation of the fuel inlet opening, and many other small details.

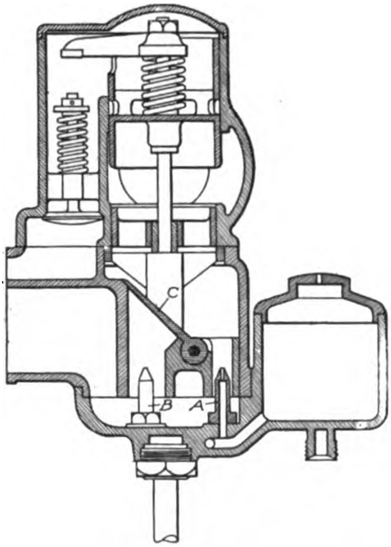


Fig. 131. Saurer (Swiss) Carbureter with Two Standpipes

Probably the latest idea in vaporization is that brought out within the past half year as a feature of the Zenith (French) carbureter, Fig. 133. This is but a modification, in a way, of the Venturi plan, for the latter shape is actually used for the vaporizing chamber. The new idea consists in leading into this mixing chamber, not one but two tubes. Of these, one is the ordinary spray nozzle and does not differ from that used on hundreds of other devices. The second, however, is very different, and while

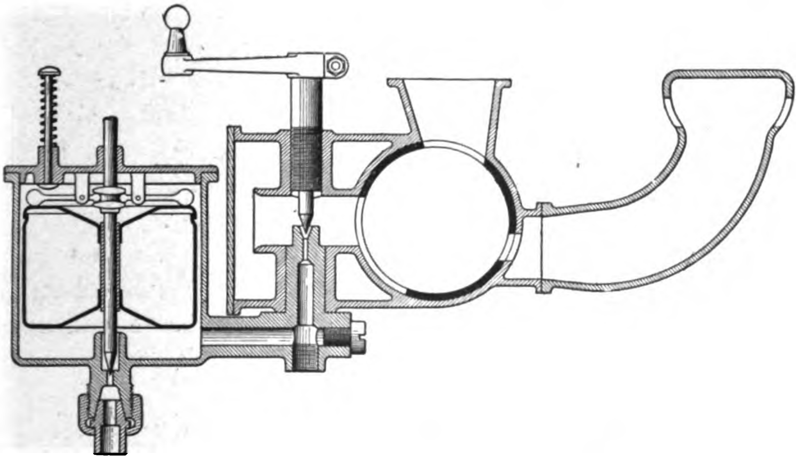


Fig. 132. Benz Carbureter Showing Hand Regulator for Needle Valve

leading into the same mixing chamber, does so through the medium of a secondary chamber or standpipe, to which the suction of the engine has access. If this suction is strong, more gasoline is drawn into the secondary chamber, from which it may enter the spraying zone.

The ordinary nozzle is of an exact size, and consequently can pass only a certain amount of fuel, always at the same speed. With the additional nozzle, this does not hold, and being of large diameter (comparatively), the flow through it depends wholly upon the engine suction, which varies at all speeds, often at the same speed upon different occasions. Stearns (American) also uses two nozzles.

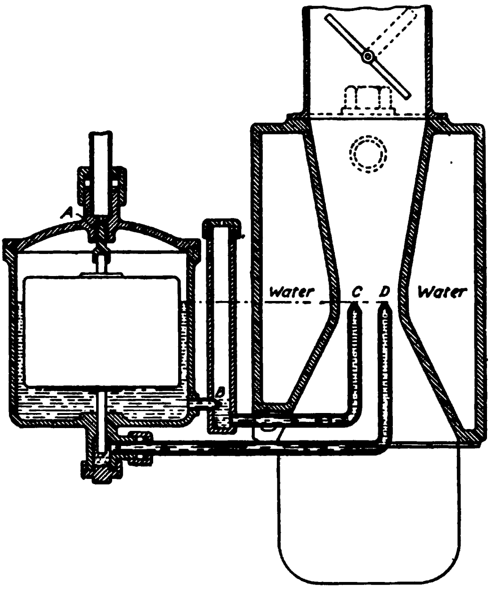


Fig. 133. Zenith (French) Carbureter

In starting a car or any engine, whether located in a car or not, everything should be inspected so as to know if all is right before attempting a start. With the novice this is somewhat of a task, but to the old hand it is so much of a routine task that he does it unconsciously.

Troubles. *Engine Should Start on the First Turn.* If all conditions are right, the carbureter is primed and the engine will start on the first turn of the crank. If it does not do so there is a source of trouble which must be remedied first and it is useless to continue cranking. This may lie in the fuel system itself, but exterior to the vaporizer, or it may be in the ignition apparatus. It is well in a case of this sort to start with the gasoline tank and follow the fuel through each step until it apparently reaches the combustion chamber in the form of a properly proportioned mixture of gasoline and air.

To start with the tank—is there enough fuel in it not only for starting purposes, but enough to allow of making the proposed trip? This is readily ascertained by unscrewing the filler cap and inserting a measuring stick. For the purpose a graduated rule is good, but not necessary; any stick or small branch of a tree will answer, or, lacking all these, a piece of wire can be used. A string tied to a very small weight will also do. also a hat pin

Having verified the presence of fuel, the next question is: Does it reach the vaporizer as it should? Nearly all carbureters have a drain cock at the lowest point. Open this and if fuel flows out in a steady stream you may be sure that the pipe from the tank up to this point is not clogged. In case the carbureter does not have a drain cock, the same result can be effected by holding the primer down for a long time when the gasoline will overflow through the air inlet.

In either case, if there is no sign of gasoline when the tank contains plenty, it is apparent that the feed pipe is clogged and the method of procedure is as follows: Shut off the cock below the tank so that none of the previous liquid can escape, then drain off the carbureter and pipe into a handy pail. Next open the union below the cock in the feed line and the one at the other end of the same pipe. At both places look for obstruction. Then clean the pipe out thoroughly, using flowing water, a piece of wire, or other means which are available at the time.

Gasoline Strainer a Source of Trouble. Finding nothing here, it will be necessary to search. Look in the strainer of the carbureter to make sure that the flow is not stopped there by the accumulation of dirt and grit, filtered out of the fuel. The strainer should be cleaned often, but like many other dirty jobs is postponed from time to time.

Should this source of trouble prove "not guilty" the carbureter itself becomes an object of suspicion. Is the float jammed down upon its seat or are there obstructions which prevent the flow of fluid? Is the float punctured, or has one of the soldered joints, if a metal one, opened, or is it fuel-soaked, if cork?

A Bent Needle Valve Stem. To attend to this sort of trouble, disconnect the priming arrangement, take the cover off of the float chamber (it usually is screwed on with a right-hand thread), and take the float out. An examination of the float, Fig. 134, will disclose whether it is at fault in any of the above-mentioned ways, all of which are comparatively easy to fix. If the float was jammed down, perhaps by priming, the act of taking it out will cure that, provided that the stem of the float is not bent and the needle valve or its seat not injured. If the seat is scored it should be ground in just like any other valve, using oil and fine emery. A fuel-soaked cork should be thrown away if another is at hand to replace it, but if not, the cork float should be moved in its position on the stem so that it sets higher in the liquid. In other words, move the cork a sufficient amount to compensate for its loss of buoyancy.

In the case of a punctured float of metal or loose solder, the only real remedy is to resolder in either case. It usually happens that a soldering outfit is not available out on the road and some form of makeshift will be necessary to allow of reaching a place where a soldering iron may be had. If the puncture is on the bottom, it is sometimes possible to accomplish this by inverting the float so that the hole comes at the top where the gasoline seldom reaches. If the flow be reduced to make sure of this, it is possible to reach a place where a soldering iron may be procured.

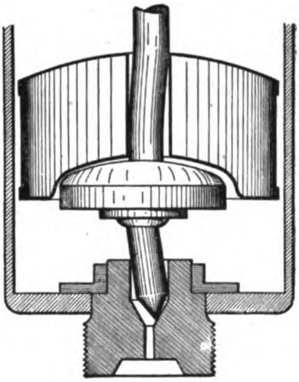


Fig. 134. Bent Needle Valve.

A remedy which might be tried in an extreme case of this sort is to fill the float to make it heavy, so that it will have a tendency to sink. Then take a small diameter spring, cut off a short piece of it and place it in the float chamber so that it opposes the sinking action of the now-heavy float. By carefully determining the length, and thus the strength of this spring, the same action is obtained as would be had if the float were working all right. Of course, if the entrance of the liquid fuel is such that the sinking of the heavy float tends to close rather than open the gasoline inlet, the spring would have to be on the bottom and fairly strong so as to oppose the action of gravity. But if the float works downward to open the gasoline passage, the spring will be at the bottom and very weak, simply being there to prevent an excessive flow.

Throttle Loose on Shaft. Now the carbureter trouble has been reduced to a minimum. The remaining troubles might be centered in a clogged spraying nozzle. But this nozzle is readily removed, and with it the trouble, if that be the offending member. If the spray is proven *O. K.*, the throttle is ready for attention. If of the butterfly type it may have become loose on its shaft, or what is the same thing, the operating lever may be loose. In either case the shape and weight are such that it would swing into such a position as to cut off the entrance of gas to the inlet pipe and thus to the cylinder. If the throttle is of the circular sliding or piston form it may not be connected to the throttle rod, but is stuck in such a position as to prevent the passage of gas. This sometimes happens when running, and then, apparently, closing the throttle does not stop the engine. The writer had this happen to him once at a time when it was absolutely necessary to stop. The only way that trouble was averted was by the instantaneous closing off of the switch and the hasty application of the brakes.

The last hope of finding trouble in the carbureter system rests with the inlet pipe. If the source of the trouble is not found elsewhere, take this off in search of misplaced waste or similar substances. The size of the pipe is such that anything in it large enough to cause trouble may be instantly seen and removed. The only exception to this is a small hole in the inlet pipe casting, which will not only cause trouble with the mixture at all times, but is also very hard to find, particularly if it happens to be of very small diameter, caused by a single grain of sand, for instance.

The valve or cock controlling the flow of liquid from the tank should be examined frequently and care be taken to keep it in good shape. It must act hard and must be tight, so that no gasoline flows when it is supposed to be shut off. The reason for having it act hard is to prevent it jiggling shut during a long run which results in the engine slowing down and stopping without any apparent reason until the tank is looked at when the supply is found to be shut off. A method of fixing it—which, in general, is not to be recommended—is to open the cock and then hammer the handle so as to jam it tight against the seat, but in the open position. This makeshift will answer until a place is reached where the taper seat can be reground or tightened in place, if that is what it needs. In case the driver does not wish to do this, and the cock is of the two-way type, open when the handle is parallel to the axis of the pipe, it may be tied in the open position by passing a cord around the cock and pipe.

STARTING DEVICES

As far as starting is concerned, motors have been turned over by hand ever since the industry sprang into being about 1885. But as sizes grew larger and larger while the number of cylinders multiplied, this became more and more of a task. With progress in mechanical construction came progress along lines of theory, such as increased power due to greater compression. This worked out nicely but made the resulting engines even more difficult to crank over. Finally the stage was reached on racing cars, with engines of immense size and compressions of 110 pounds and upwards, which one man could not turn over regardless of his strength. So at such times and places as the Vanderbilt Cup Races of 1907 and 1908, it was not an uncommon sight to see five or six men on the end of a six-foot bar turning a big racing engine over to start it.

This condition did not obtain in the case of ordinary engines, but even these became so large that starting was a strenuous, not to say dangerous, task. Under these conditions, a call arose for self-starting devices, which, while it was stilled by the advent of engines with more cylinders giving the same power with a smaller bore and by the more recent development of much lower-powered engines, nevertheless still exists and with surprising though latent strength.

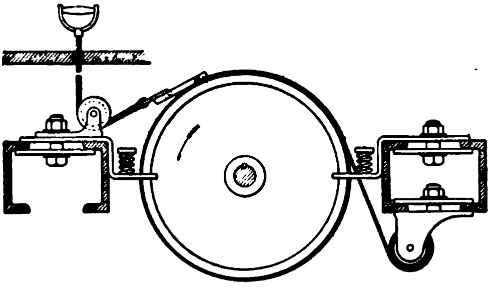


Fig. 135. Strap Starting Device.

Speaking broadly there are three classes of starting devices worthy of mention, viz, the *mechanical* or *spring actuated* devices; the *compressed fluid* devices; and the *electrical* starters.

Mechanical Systems. In the first class properly belongs any mechanical contrivance by the use of which the driver of the car does not have to "wind up" the motor by means of a rotating lever directly attached to the engine, and, therefore, liable to a "back kick," which is the real objection to the cranking of the engine. This class includes such devices as the coil spring, wound up by the running of the engine after having been once started by hand. This is wound up tight and then the engine automatically cuts itself out, leaving the spring tense. To use the starter, the spring tension is suddenly relieved by a suitable device and the tendency of the spring to unwind results in a rotary motion which turns the engine over.

In this class also belong that type of starters in which a strap is pulled upwards or sideways, this motion rotating the flywheel or other suitable drum. A spring returns the strap to place, so that it may be used over and over with no appreciable interval. In case the engine backfires or tries to rotate backwards, the strap simply slips on the drum or is pulled out of the operator's hand, with no attendant danger. Fig. 135 shows a commercial form of this type in which the strap is plainly seen. On the right is the drum upon which the strap is wound and held by means of a spring. The band or strap is normally held away from the drum by the two clips and springs, one on each side, but, when force is exerted upon it to turn the engine over, these allow the band to take hold. In this way there are no friction losses from the dragging of the band when it is not in use. The angle of contact is very large, being nearly 450 degrees, so that a small coefficient of friction (such as this device would have) is sufficient to do the work.

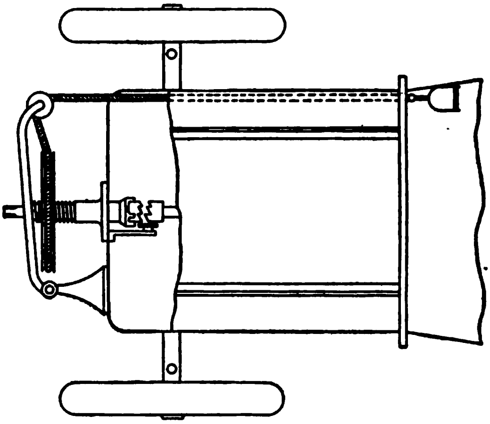


Fig. 136. Mallins (English) Mechanical Starter

This principle is utilized in another starter, which has a side lever in place of the handle, the remainder of the parts being the same. Another one of the mechanical starters uses the side lever, but for the actuating means has a modification of the worm and gear. A deep spiral groove *G*, Fig. 136, is turned in the prolongation of the shaft and a pair of dogs set into this. The latter, Fig. 136 and Fig. 137, are constrained to move in a straight line, so that only the shaft rotates. By operating the hand lever the other lever carrying the dogs is moved, and through the medium of the spiral groove turns the shaft around, the total motion depending upon the length of the spiral and the amount of the lever motion. It may, however, be such as to afford three turns of the shaft, which usually are sufficient for starting purposes. A jaw clutch prevents the rotating of the engine from being retroactive, *i. e.*, from working the starting device in the opposite direction.

Very similar to this is the form in which a rack and gear are employed, the latter arranged on the crank shaft with a clutch, and the former contacting with it. Motion of the hand lever draws the rack across the car, thus rotating the shaft, and with it the engine. Still other mechanical starters have been brought out and, in some cases, successfully used, but in the main these follow along the lines of some of the above-described contrivances.

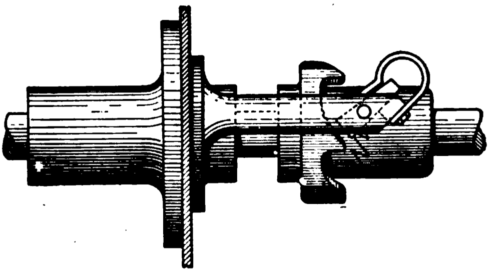


Fig. 137. Detail of Mallins Mechanical Starter

Compressed Fluid Systems. Owing to the fact that all of the mechanical devices require more or less physical exertion, the difference between them and the ordinary cranking being a linear instead of circular motion, and the elimination of all danger, the use of a fluid pressure system in which there is neither work nor danger is more desirable and deservedly more popular. After cranking over a big motor the notion of pressing a button to start it is particularly attractive.

Nearly all of these use the air, but some employ the exhaust gases. The advantage in so doing lies in the elimination of the compressor and the attendant mechanisms to drive, connect, and disconnect it. This method, besides making for simplicity, saves weight, and the elimination of extra parts allows the driver more peace of mind. All this is said with the proviso that the arrangement works and works at the desired time, without which it is useless. The doubt here expressed is a large item, and has proved the downfall of many an apparently good mechanism.

The system just spoken of may take either one of two forms, viz, the actual exhaust waste gases may be drawn off from the motor, stored in a tank, and used as a source of energy; or the mixture may be taken during the compression stroke, just before ignition, so that the starting fluid is a combustible mixture and differs in the strict definition from carbureted gas only in being under great pressure. This latter is also stored in a tank.

The complaint made against using the exhaust is that the starting gases so weaken and impair the mixture from the carbureter that a considerable number of turns are necessary to start the machine. This, in turn, means a very large gas storage tank, which adds materially to the weight of the car. The exhaust pressure, in a well-designed engine running under normal conditions, seldom exceeds 45 pounds, so that a high pressure may not be obtained from this source.

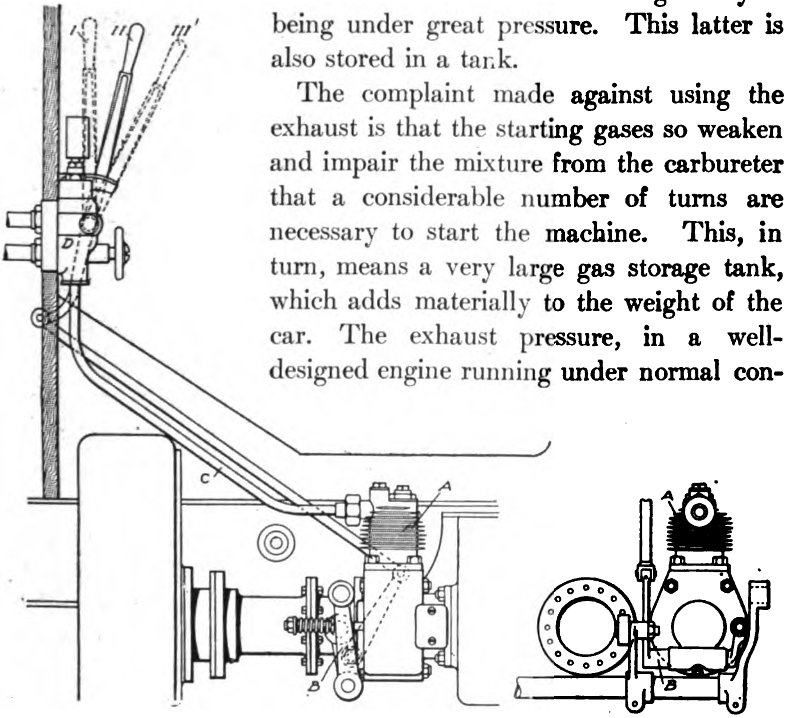


Fig. 138. Principal Parts of Saurer Air-Operated Starter

The method of utilizing the compressed gases has the same detrimental feature, but not in so marked a degree, *i. e.*, that a wide range of pressure is impossible. However, a very high pressure in comparison with the other method is obtainable. The compression usually runs from 70 pounds upward, and it has been known to be as high as 110 pounds, so this would give good, if not maximum, results.

With an outside and independent compressor any desired tank pressure may be obtained, and, as a matter of fact, the majority of these systems do use it higher than any of the figures thus far given. In the Saurer system, 225 pounds is maintained in the reservoir at all times, while the Renault method utilizes 250 pounds. Other pressures are used, all being above 200.

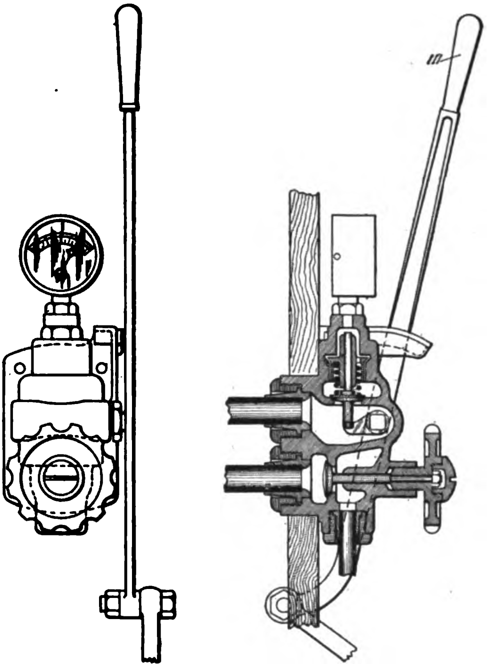


Fig. 139. Dashboard Control of Saurer Starter

As usually constituted, a fluid-pressure system consists of a compressor as a source of pressure, a storage tank, a distributing valve, and a lever, button, or other operating means. In use, the engine must be started by hand in the first instance. This creates a source of power, whether it be exhaust gas, compressed gas, or air from a compressor driven from the crank shaft or cam shaft.

Saurer. Fig. 138 shows the essentials of a system in which the air-cooled compressor is driven off of the main driving shaft just ahead of the gear case. The hand lever shown on the dashboard, when forward in the position *I*, throws the compressor clutch in, and it then charges the storage tank. The valve to the latter is set at 225 pounds, and when that pressure is reached the clutch is automatically cut out and the compressor stops working.

A is the air-cooled compressor, which is driven from a forward extension of the transmission shaft, as soon as thrown into engagement by the linkage shown at *B*. This linkage is operated from the dashboard as previously described. The air when compressed, passes through the pipe *C* to the distributor *D* on the dashboard, and thence to a storage tank not shown. The left-hand end is a side view, while at the right is a small detail view taken from the front.

When it is desired to start the car the lever, shown in larger size and more detail in Fig. 139, is pulled backwards as to position III, the compressed air from the tank flows up through the governing valve and thence to the distributor. The latter is situated high up between cylinders *2* and *3*, and is driven by miter bevel gears from the crank shaft so as to have the same speed of rotation as the latter. This consists of a revolving sleeve in which are cut ports, one for each cylinder. As the sleeve turns, Fig. 140 (with the crank shaft), these ports register in turn and in the proper firing order, with passages which connect to the individual cylinders. The air under pressure is admitted by the governing valve, on the dash previously spoken of, to the interior of this sleeve, and thence to the proper cylinder.

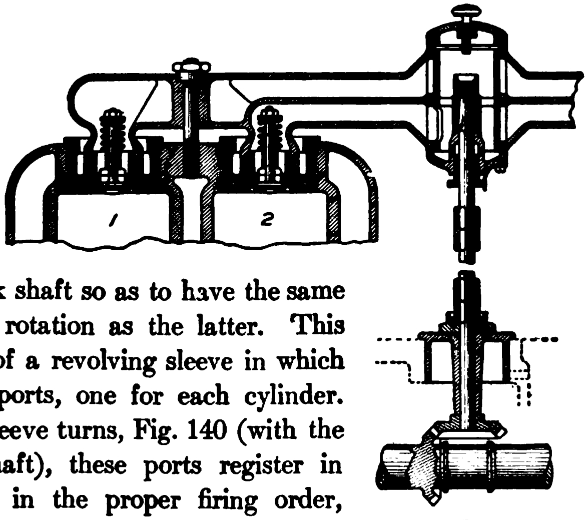


Fig. 140. Distributor Valve Details of Saurer Starter

As shown in Fig. 140, this is open to cylinder, *2*, and in this situation the air will pass into that one and drive the piston down. This must necessarily turn the crank shaft around, and with it the distributing valve, which thus registers with the cylinder next in the firing order, *4*, or whatever it may be. From this it is plain that the tank will continue to furnish compressed air to the cylinders, in proper rotation, until all of the supply has been exhausted or the engine has been started and the supply cut off. Another and different view, Fig. 141, shows the dashboard with the control mechanism, the small, air-cooled compressor being in the foreground.

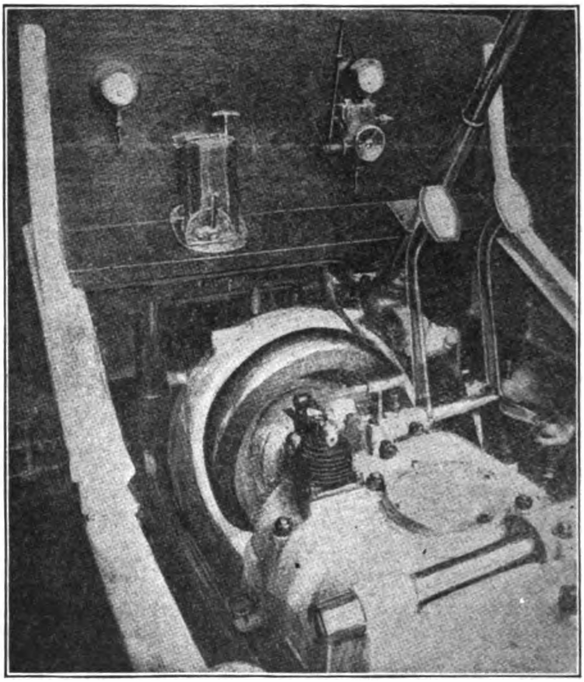


Fig. 141. View of Saurer Starter in Place

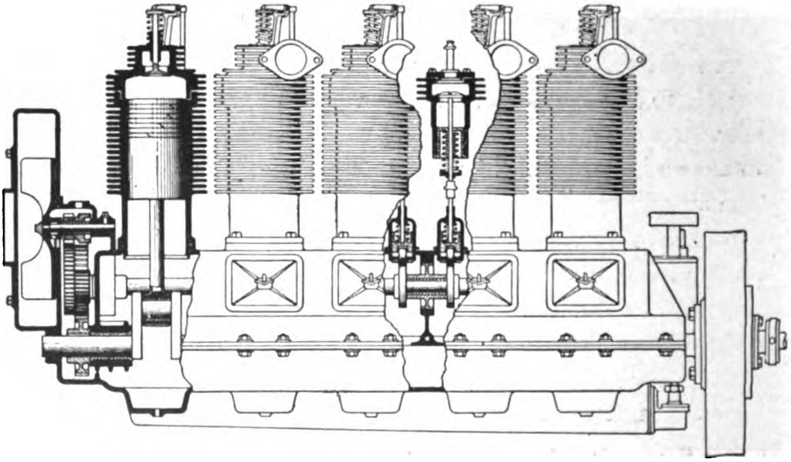


Fig. 142. Rowe Starter Applied to Five-Cylinder Engine

Rowe. Another starting scheme of much similarity known as the *Rowe self-starter*, is that applied to one specific design of air-cooled car, and shown in Figs. 142 and 143. As is there shown, a source of compressed air is connected up to the fuel inlet system just beyond the carbureter. Then, to start the engine, the air supply is turned on. This rushes through the carbureter, picks up gasoline, vaporizes it, and thus fills the cylinders with an explosive mixture. Since the production of a spark in any one cylinder is an easy matter, it is plain to be seen how this starter works. The engine, to which this is fitted, starts readily for the simple reason that it has an odd number of cylinders, five, and thus has one cylinder always in the firing position, and ready to be started.

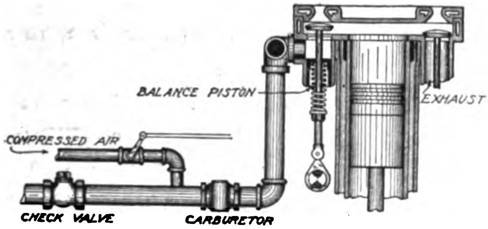


Fig. 143. Section of Rowe Starter

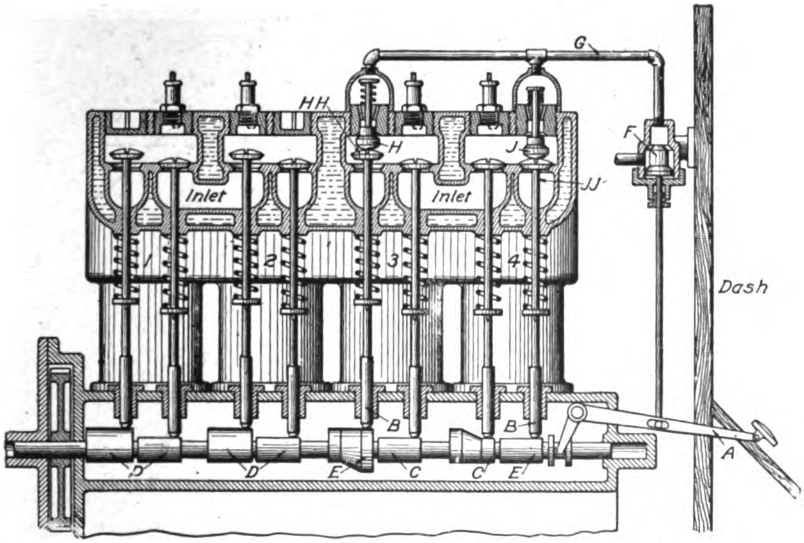


Fig. 144. English Starter Using Two Cylinders as Air-Compressors

English Devices. In Fig. 144 are shown the essential parts of an English starting device which converts two of the engine cylinders into air compressors by shifting the cam shaft longitudinally. This is done by the foot pedal *A*, which moves different cams, or rather, a different part of the cams *C* and *E* under the push rod. The altered shape of the new cams causes the function of the cylinders to be changed into air compressors, which then act to store air under pressure in a tank. To start, the action is reversed and the air flows into the cylinders, moving them downward, and thus starting the engine.

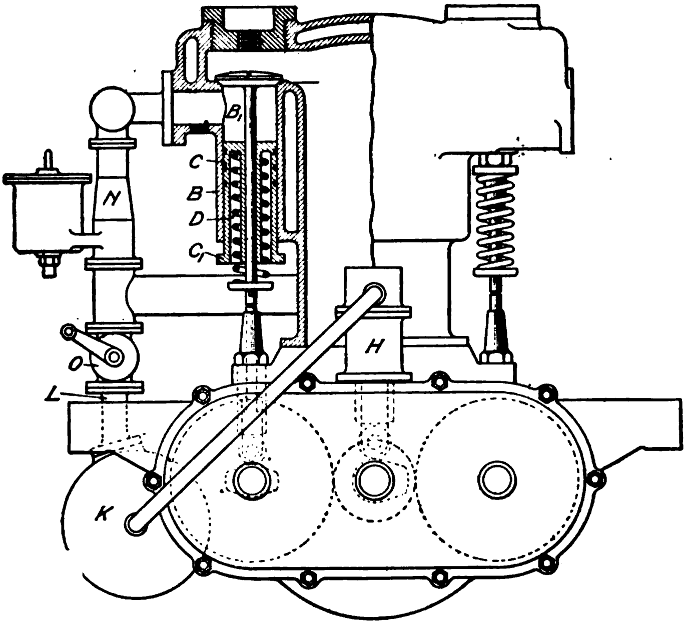


Fig. 145. Gore (English) Fluid-Pressure Starting Device

An English starter, that of Gore, Fig. 145, sends compressed air through the carbureter, thus filling the cylinders with an explosive mixture which is readily ignited. *H* is the compressor driven from the crank shaft by the cam shown dotted. The compressed air is piped to the tank *K*, which communicates with the lower end of the inlet pipe at *L*. *O* is the throttle which puts the tank into action. This being opened, the compressed air rushes through the carbureter *N*, picking up some gasoline, and vaporizing it. Passing on through the inlet pipe, the pressure is sufficient to open the inlet

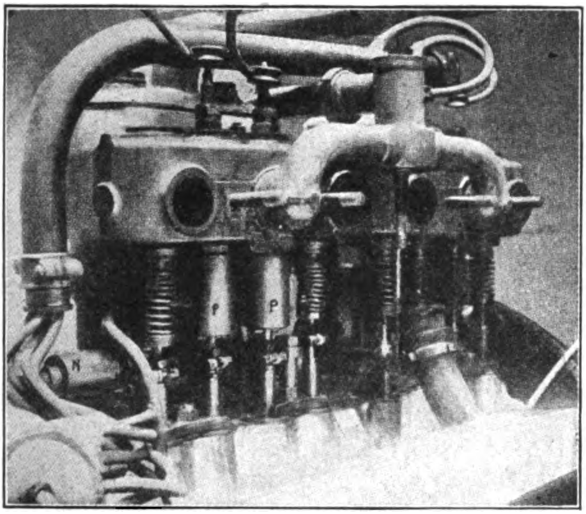


Fig. 146. **Doué (French) Starter in Place on the Engine**

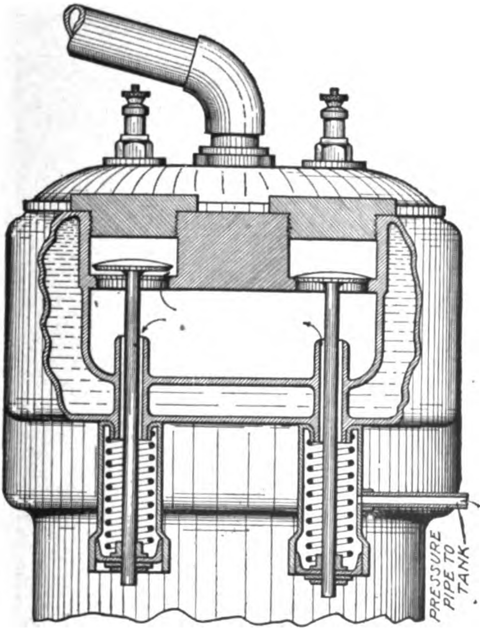


Fig. 147. **Doué Pressure Admission to Valves**

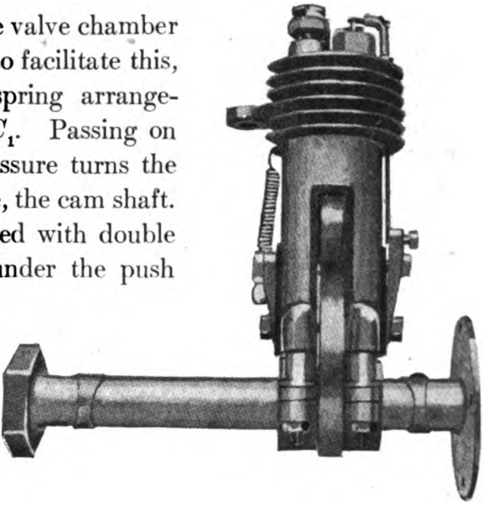


Fig. 148. Detail of Doué Air-Compressor

valve, the lower part of the valve chamber *B* being specially formed to facilitate this, as well as the special spring arrangement, shown at *C B D* C_1. Passing on into the cylinders, the pressure turns the engine over, and, of course, the cam shaft. The inlet cam shaft is fitted with double cams, which are shifted under the push rod at starting time. These open the inlet valve twice as often as it would be opened otherwise, and thus permit the air pressure twice as many entrances to the cylinder as would ordinarily be the case with carbureted gas. The doubling of the entrances is a very necessary provision as after the tank is once opened, the pressure falls rapidly. All this gas being carbureted gas and not atmospheric air, as soon as a hot spark is obtained, the engine may be considered as started, and the tank shut off.

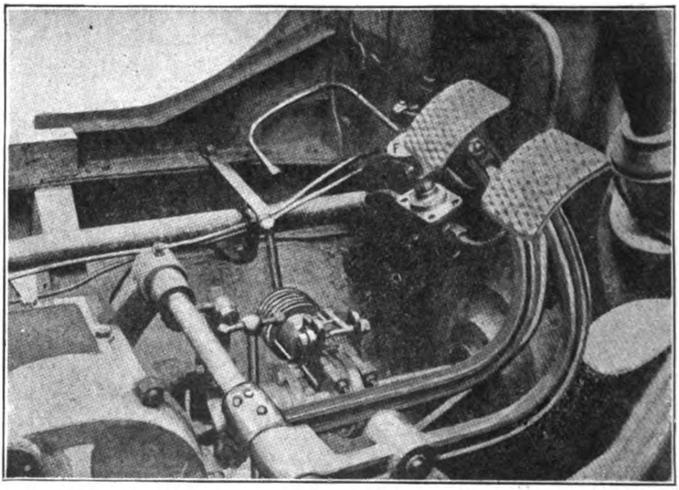


Fig. 149. Air-Compressor of the Doué Starter in Place

Although to Saurer has been ascribed the most successful of self-starters and European constructors pay license fees to him as the holder of all starter patents, that fact does not entirely eliminate originality in the matter of details. This is to be plainly discerned in the Doué, a French starting device, as illustrated in Figs. 146, 147, 148, and 149, and that of the Renault, Fig. 150. All of these depend upon a source of compressed gas, which is distributed to the proper cylinders by a timing device.

Renault. Renault's starter operates as follows: At the front end of the engine is placed a small air-cooled compressor *H* which is connected by means of the pipe *J* to the distributor *N* on the dashboard, and through that and the pipe *L* to the storage tank *R*. From the valve *N* on the dash another pipe *K* leads to the actual distributor *C*, which is driven from the cam shaft *A* by the inclined shaft *B*. This puts the air under pressure in the pipe *K* into communication with the cylinder in which the piston is in the proper position for starting, the cylinders and distributor being connected by the two-branched pipe *E*. When running, the tank is filled, and then the compressor is thrown out, as described later. Now, with a tank *R* full of highly compressed air, if it is desired to start, the handle *D* is pulled upward, which opens an internal port, and allows the air to pass through to the pipe *K*, which, as mentioned before, leads to the distributor and cylinders.

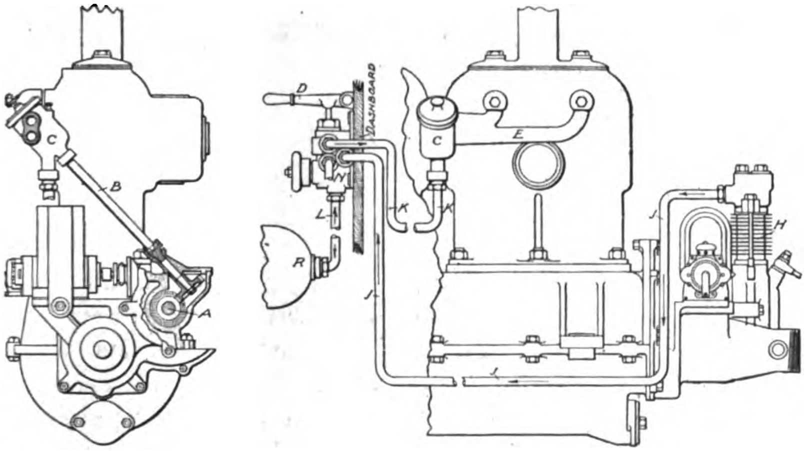


Fig. 150. Component Parts of Renault (French) Self-Starter

A prominent feature in the Renault system may be mentioned briefly. This is essentially the same as the one just described but the control of the compressor differs in that the air suction valve has a flexible diaphragm, Fig. 151, which is in contact with the tank, or, rather, to which the compressed air has access. As the pressure rises this distends until, at the predetermined maximum, it holds the air inlet open, thus preventing compression and consuming no power. Of course, as the pressure falls off from leakage or the use of air, the diaphragm changes its position to correspond, until at a certain fixed minimum pressure the suction valve will be allowed to close on the compression stroke, and thus the tank will be automatically replenished.

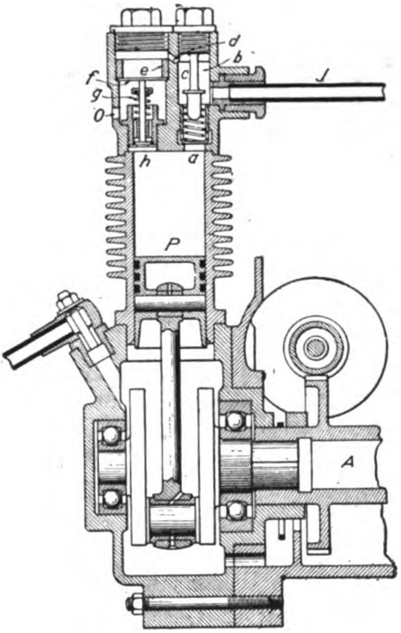


Fig. 151. Renault Air-Compressor

In the figure, *A* is the driving shaft, *P* the piston, *J* the supply pipe to the pressure tank, *h* the inlet valve, and *a* the outlet or discharge valve. Air enters the small hole *O*, passes through the inlet valve, the suction within opening it against the spring *g*. It is then compressed, passes out through discharge valve *a* and the pipe *J*. It will be noticed that the upper part of the discharge passage *b* is connected with the inlet passage by a small hole *d*. The bottom of this is closed by the diaphragm *f*, held at the periphery by a hollow nut *e*. Between this diaphragm *f* and the top of the inlet valve stem is very little clearance, and as the pressure rises, even this is decreased, until finally at the maximum point, the inlet valve is held open continuously by the diaphragm. When this happens, and until the pressure is reduced, the valve is held open continuously, and the piston simply pumps out the same air which it drew in on the downward stroke.

Scat. Any one picture of a starting device of this kind would fail to show all of the component parts, for the reason that they are so scattered, some being at the front, and others at the rear of the chassis. For this reason, the diagrammatic sketch, Fig. 152, of the Scat English starter is of more than passing interest, in that it shows all of the components. In this it is rather misleading, because parts which are actually separated by several feet are shown in close proximity. Thus, the air tank is shown nearly touching the crank case of the engine. In the actual installation, the two are separated by not less than 50 inches.

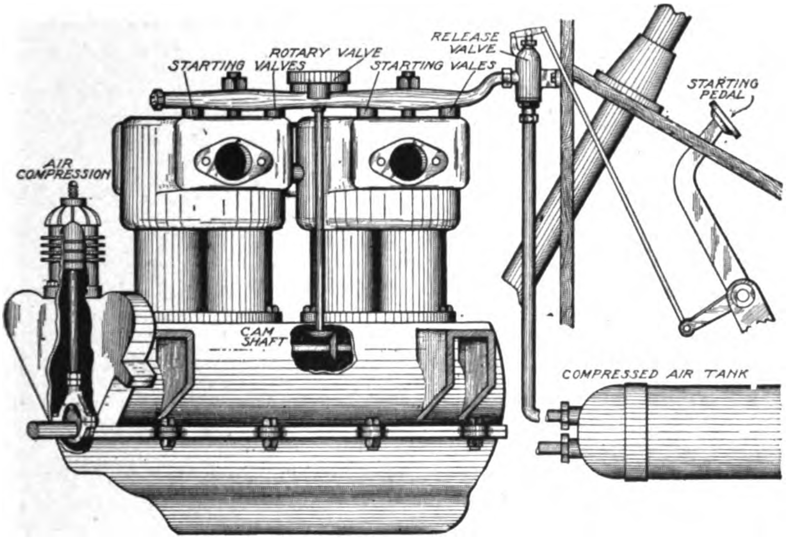


Fig. 152. Scat English Starter

There are other systems, which, while using a part of the apparatus above described, do not use all of it, and consequently differ somewhat in their action. One that was given publicity recently is based on the assumption that when the spark and throttle are correctly manipulated just before stopping, all of the cylinders but one will contain an explosive mixture. Granting that this is so, all that is necessary is a spark in the cylinder in which the piston is in the proper position for firing. This spark is effected by disengaging the driving gear and throwing the magneto armature around to a contact, the arrangement being such that on starting, the magneto gear drops back into its proper position and ignition proceeds as usual.

A decided advantage of the compressed-air system of self-starting lies in the fact that the machine is equipped with a large tank of highly compressed air which may be found useful in many ways. For instance, for inflating tires, the autoist would take a chance on starting with less air and utilize a part of the tankful to inflate his tires.

Combined Pressure and Electric Systems. The most recent starting device is in the nature of a combination of the stored pressure and the electrically operated devices. This is an American product, made in the Middle West, and very recently placed on the market, after two years of experimentation and successful tests.

The basic idea is a source of pressure, which is admitted to the cylinders by means of a system of magnetically controlled valves. The pressure utilized is that of the explosion—not the compression, not the exhaust. This, through the medium of a pressure reducing valve, is reduced to 200 pounds, at which value the tank is filled. With a full tank, the valve cuts out the supply and the driver can then close off the valve communicating with the cylinders.

For starting, this fluid pressure is admitted to the cylinder through the medium of the distributing valves, which are placed on top of the engine as shown in Fig. 153, this being a view of the apparatus applied to an automobile engine. These valves are operated by means of an electric current, diverted from the regular ignition source, the only necessity being a direct current. This current is led through an ordinary timer and from there to the distributing valves in the cylinder heads. Thus it is that the valves are opened in proper rotation, each at the top of the piston stroke, which, while it is the correct position for the igniting spark in ordinary running, is also the correct position for the starting effort. So through the medium of the magnetically controlled valves the pressure is introduced to the proper cylinder at the proper moment. Referring to Fig. 153, *A A* are the magnetically controlled valves, to which the wires *D D* lead. *B* is the supply pipe from the storage tank. The shut-off valves *C* are operated by a hand lever on the dashboard and just above them may be seen the operating rod. If a car has a double ignition system, the battery-timer system may be used for the starting by putting the starting switch in that circuit. Then by throwing the ignition switch to the battery and timer, and the starting switch to the starting position, the gas is admitted to the proper cylinder, the engine is started; next the ignition switch may be thrown over to the running position, and the starting switch cut out.

Electrical Starting Systems. Of the three means of self-starting, the electrical method, paradoxical as it may sound, is by far the most simple. This depends for its action mainly upon two conditions and if these do not exist the starting means are useless. The first and foremost is that the piston and piston ring construction should be such, coupled with correct assembling, that the engine will always retain a compressed charge in a state of high compression. The second condition is that at low speeds, the ordinary igniting dynamo, usually called a *magneto*, is incapable of delivering a spark of sufficient intensity to ignite the mixture, *i. e.*, it must be rotated rapidly in order to be effective.

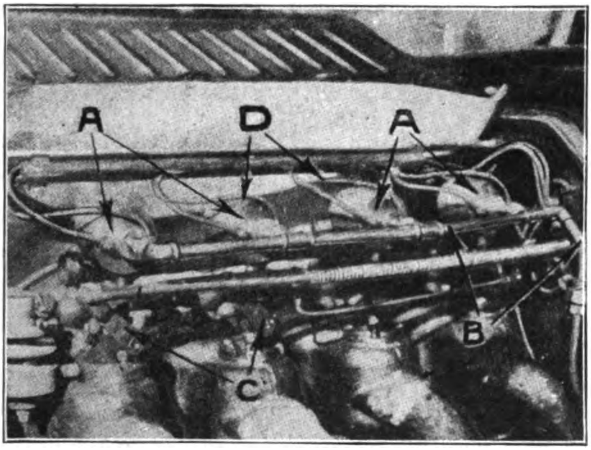


Fig. 153. Combination Electro-Magnetic Starting System

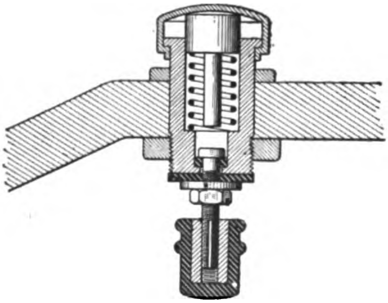


Fig. 154. Steering Wheel Starting Switch
Bosch Magneto Company.

The first condition is usually met by modern cars, a number of motors achieving credit by always starting on the spark, *i. e.*, they retain, upon stopping, the compression in one cylinder and may be *started* by turning on the ignition and producing a spark in that cylinder. If the ignition system fails to give a spark or the one produced is not of sufficient intensity to fire the charge, the second condition above is not fulfilled so that the first, alone, is useless for it means cranking by hand.

To fulfill the second condition, a means may be provided for rotating the magneto armature at a high speed for a sufficiently long time to ignite the charge regularly. There are two ways of doing this, both mechanical and both spring-actuated, but differing in detail. In each one of these, there is fitted some form of dashboard or steering wheel push button which sets the starter into action. One of these is shown in Fig. 154, as attached to the arm of the steering wheel so as to have the button below the arm.

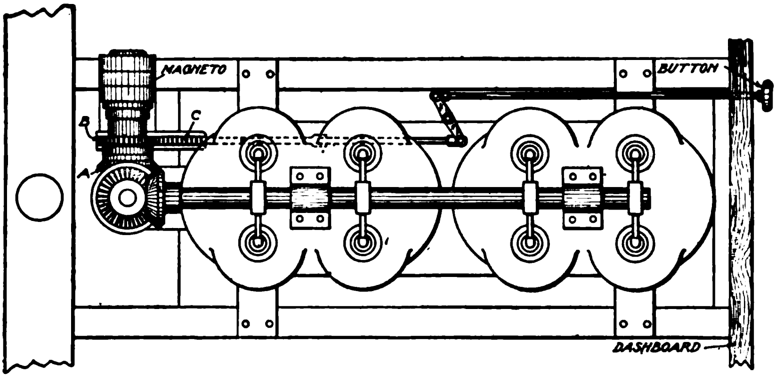


Fig. 155. Electrical Starter on the Moon Car
Moon Motor Car Company, St. Louis.

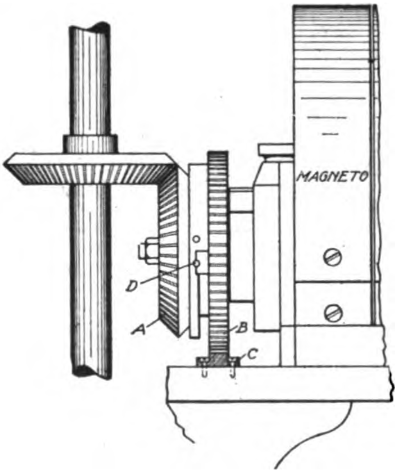


Fig. 156. Details of Rack Device on Moon Starter

Moon. Fig. 155 shows the whole scheme of an electrical starter as applied to the 1910 models of the Moon cars, made by the Moon Motor Car Company, St. Louis, Mo., and Fig. 156 gives some of the parts more in detail. In this the magneto is located at the front of the engine crosswise of the frame, and is driven by bevel gears from the vertical shaft which also drives the overhead cam shaft. Back of the bevel gear A on the magneto shaft is a spur gear B, which meshes with the rack C. The latter, as seen at C in Fig. 155, extends parallel to the engine and is directly connected to the button on the dashboard. By pressing the button, the spur gear can be rotated backward through one-third of a revolution whereby a spring inside of the bevel gear A is wound. When the button is released, the spring drives the spur gear B and hence the magneto armature shaft upon which the gear is secured. Thus an electric impulse is generated and a spark produced in the proper cylinder. The bevel gear A is loose on the shaft, and the two gears have a certain relative motion, but when the spring is unwound, they are locked together by a catch or shoulder D, so that the armature is perfectly timed.

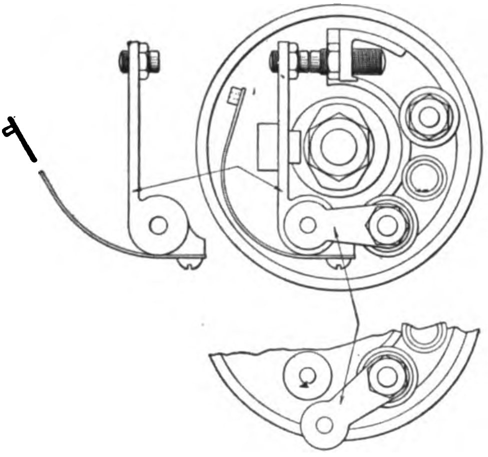


Fig. 157. Contact Breaker of the Eisemann-Lavalette (French) Magneto

Unterberg and Hulme. A similar starter, in which a spring is used to rotate the armature when the button is pressed, is used on the Unterberg and Hulme, a German magneto imported into this country by J. S. Bretz & Co., New York City. In this, as soon as the armature has reached a suitable speed of rotation, the device is automatically thrown out of action and the armature revolves at a uniform speed.

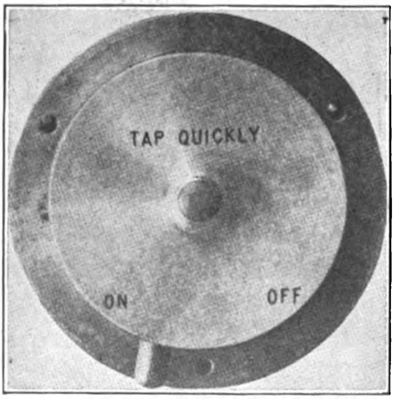


Fig. 158. Simms Switch Starter
Simms Magneto Company, England.

Accumulator and Special Switch. In the starting mechanism put out by the Simms Magneto Company, an English firm, an accumulator or storage battery is used as the source of starting current, while a special starting switch has been developed for this purpose. The contact breaker of the magneto differs from the conventional, of which an excellent example is shown in Fig. 157. This is normally in contact; while in the Simms device the contact breaker is so designed as to have the points normally separated, causing the armature primary circuit to be opened rather than closed. By throwing the switch, shown in Fig. 158, to the *on* position, and tapping the central button quickly, a current from the storage battery is instantly passed through the primary winding, and a very quick break causes an intense spark. This usually starts the engine. After being started, the magneto runs in the ordinary manner.

This describes the main forms of starting devices, all of which are designed to dispense with the troublesome and dangerous act of cranking an engine. After the engine has been cranked once and with a starter, which is sufficient to start the motor every time thereafter, the driver of a car is concerned principally with the transmission of that engine power to the road wheels in a manner which so conserves the energy and thus, in an indirect manner, the fuel, that the greatest speed or most power may be obtained at the least expense.

Acetylene Starting Systems. A recently developed type of starting device, which is commencing to find extensive application to modern automobiles, is that based upon the injection into the cylinders of small quantities of acetylene gas, which forms an explosive mixture with the air already in the cylinders and thus enables the motor to be started on the spark.

Systems of this kind, taking the gas from a prestolite tank, in which the acetylene is stored under pressure in acetone—a system of gas storage that is in common use for automobile illumination—have been found to be very reliable, and to insure the starting of the average four-cylinder motor in ninety-eight out of one hundred trials, under ordinary conditions.

The remarkable reliability of these systems undoubtedly is due to the fact that acetylene forms an explosive mixture with air throughout a wide range of proportions, it being almost impossible to render the mixture either so lean or so rich that it will not ignite. Besides this, the explosion of an acetylene mixture is very violent, so that even though the starting mixture is exploded without compression, as is necessarily the case, the explosion pressure will rise nearly as high as that of a *compressed* gasoline mixture, thus affording a sufficiently powerful "kick" to get the motor under way.

One of the best acetylene starting systems is that illustrated in Fig. 159, in which *A* is the gas storage tank, *B* is a stopcock for admitting gas into the small reservoir *C*, and *D* is another stopcock to permit the gas in *C* to pass into the cylinders by way of the pipe *E*. The gauge *F* shows the pressure in the reservoir *C*, so that when a desired pressure is reached further gas from the tank *A* can be shut off by closing the stopcock *B*.

This arrangement permits the measuring of a definite quantity of gas into the cylinders, and by a little experimenting with any given engine the pressure that should be shown on the gauge before shutting off the gas from the tank can be so definitely established that the assurance of an explosive mixture in the cylinders, capable of being ignited by manipulation of the ignition, is made almost unfailingly positive.

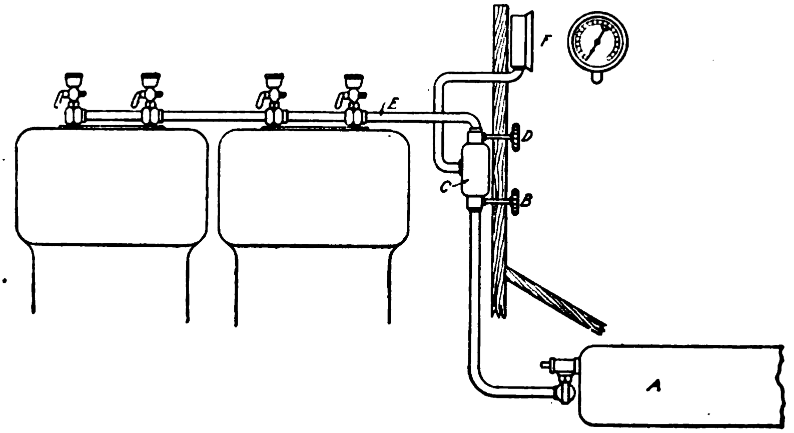


Fig. 159.

Other types of acetylene starting systems, in which there is lacking the small reservoir *C* for controlling the quantity of gas admitted to the cylinders, depend solely upon the judgment of the operator for such control, the result being that these are less reliable than the type illustrated in Fig. 159.

FUEL SUPPLY

For storage of the fuel required for the propulsion of a car, and to feed the fuel to the carbureter, many different systems are in use.

Tank Placing. In automobiles the gasoline tanks are generally placed under the front or rear seats, or under the frame at the rear. In many types of runabouts and roadsters the tank is placed above the frame at the rear.

Fuel Feeding. When the tank is at the rear or when it is under the front or rear seat, no special provision is necessary, under ordinary circumstances, to insure a positive flow of the liquid fuel to the carbureter.

Gravity. With the tanks placed high, the gasoline can be depended upon to run down to the float chamber by gravity, except that in mountainous districts it sometimes is found in climbing very steep hills that the angle becomes such that the fuel will not flow, especially when the tanks are under or back of the rear seat, or when they are nearly empty.

A means of getting around this difficulty is to place on the front of the dashboard, behind the engine and under the bonnet, a small auxiliary tank of one or two gallons capacity, from which there is a direct pipe leading to the carbureter. When the car is in a level position, this auxiliary tank fills automatically from the main tank, but a simple valve prevents the contents of the auxiliary tank from running back when the machine is tilted up. In this way a sufficient supply for 15 or 20 miles running is placed in a position to reach the carbureter under any possible road condition.

Air Pressure. With the tanks placed low, whether under the frame or above it, it is necessary to feed the fuel to the carbureter by more positive means than gravity. One of the commonest systems involves pumping a low air pressure into the tank above the fuel, so that this pressure forces the liquid out regardless of the relative heights of tank and carbureter. Ordinarily a small hand pump is sufficient to provide such air pressure, though in modern automobiles equipped with compressed-air starting devices, or compressed-air tanks for filling the tires, provision can readily be made for supplying the tanks with air from these sources for the purpose of feeding the fuel.

Exhaust Pressure. A system of providing pressure in the fuel tanks that is much used, though not so highly regarded as in the past, is to tap the exhaust piping and to take from the connection a pipe line that permits the entry of a certain amount of the exhaust gases into the fuel tank. A simple automatic valve controls the pressure and shuts off the admission of gas when the pressure rises above the very low maximum required. In a system of this character there is no possible danger of fire, not only because the exhaust gas is very quickly cooled in passing through a length of small piping, but also because the contents of a gasoline tank are ordinarily not ignitible, because of the lack of any air to support the combustion.

Sooting up of the automatic valve is the commonest trouble with this system.

Fuel Pumps. In a few automobiles, instead of the use of a carbureter with a float chamber, the expedient has been successfully employed of providing a small gasoline pump, constantly driven by the engine as long as it is running, and so pumping an excess of gasoline from the tank through the carbureter chamber, whence the surplus is returned to the tank through an overflow, placed at a height to maintain constant by a proper level.

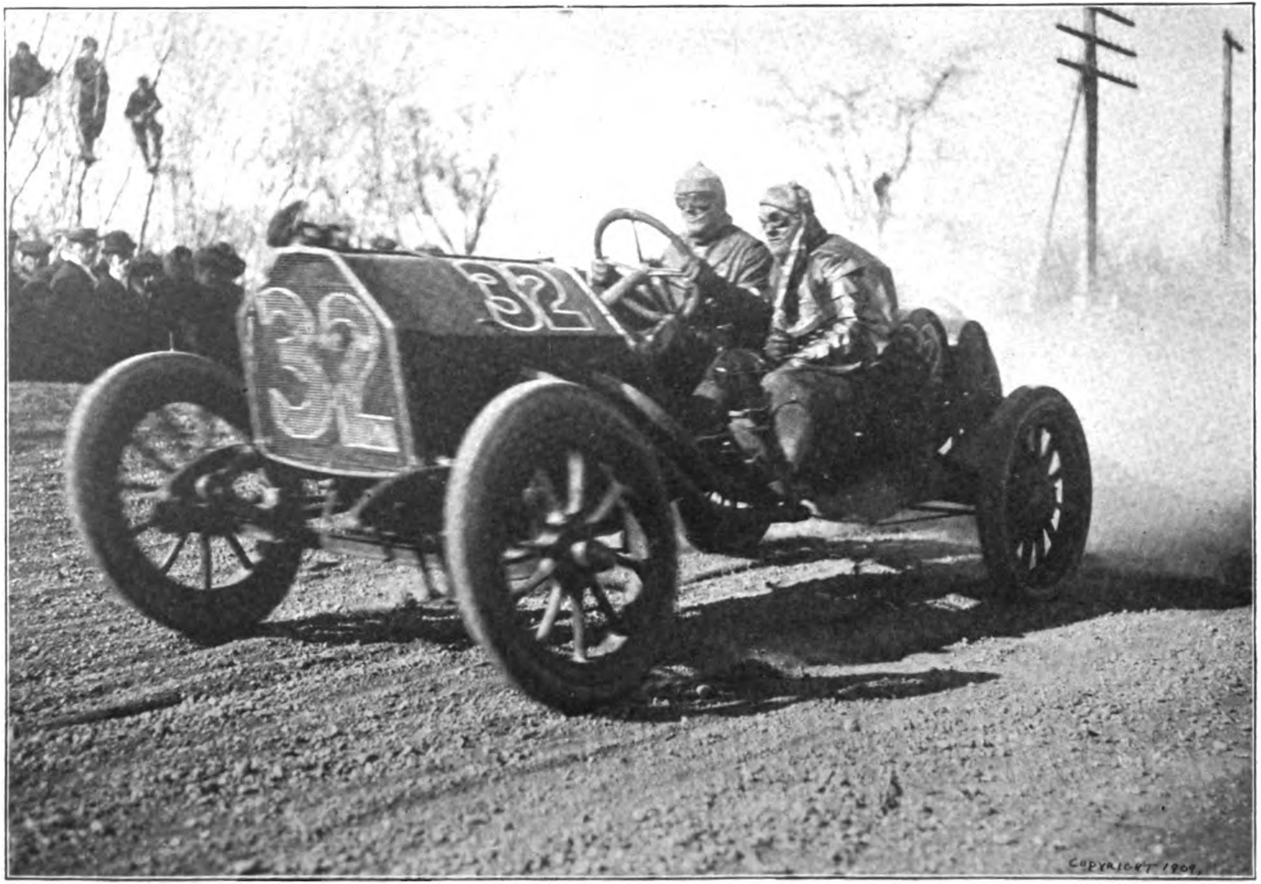
Piping and Connections. In arranging the piping system for the fuel supply of a gasoline automobile, the first essential is to use a soft brass or copper tubing that can be depended upon not to break from the vibration to which it is subjected.

As a further safeguard against breakage, and to allow alterations in the relative positions of different parts, due either to the straining of the machine while it is in use or to a change of adjustments when it is disassembled or reassembled, loops or coils introduced at proper points in a pipe line are of great advantage.

Stopcocks close to the tanks are an excellent safeguard against fire, since they permit the shutting off of fuel supply in the case of any breaks in the line. Such safeguards always should be provided.

Reserve Tanks. To guard against the annoying mishap of having the gasoline give out while an automobile is in use, perhaps remote from any source of supply, many cars are now provided with reserve tanks, in which there are held back one or two gallons of the motive fluid, so that this reserve can not be used except when it is fed into the system through the deliberate intent of the operator.

In its simplest and one of its best forms, a reserve tank takes the shape of a partitioned-off portion of the main tank, into which the gasoline automatically flows through an opening at the top when the tank is filled, but from which it can not pass to the carbureter, usually by way of the main tank, until a special valve at the bottom of it is manually opened.



HARROUN IN A MARMON CAR WINNING THE WHEATLEY HILL TROPHY IN THE VANDERBILT RACE

One Hundred Ninety Miles in One Hundred Ninety Minutes Without a Stop.

PRIVATE GARAGES AND REPAIRS

GARAGES

Public vs. Private Garages. Sooner or later, every car owner, present or prospective, comes face to face with the problem of housing his car in such a way as to be fairly handy, suitable for repair and adjustment work, and in most cases moderate in cost. In very large cities, such as New York and Chicago, this problem is solved in the only possible way, that is, by using a public garage. But in suburban locations and in smaller cities and towns, the convenience, and the low cost of grounds and building, compared to the high cost of probably very inferior public garage work, makes the private garage proposition a very attractive one. Having such a place close to the residence, no time is lost going to and fro, when desiring to use the car or after a run has been concluded. When repairs are needed, they may be done immediately, thus reducing the expense which might be entailed by letting them go for want of prompt attention. The monthly or weekly charge for rent is eliminated, the car is kept better, upkeep and maintenance charges are reduced to a minimum, and other material savings are effected. The private garage, then, places an automobile within reach of a large number of persons.

Many persons have a barn or other outhouse which seems so nearly suitable that a few dollars would convert it into a usable garage. Experience has proved that this will seldom turn out as satisfactorily as the specially constructed building, some later developments showing where the garage would have been more economical or better suited to the work in the long run.

Types. Having decided to build, the next point to settle is the form and the construction material. As far as the latter is concerned, there are about eight possibilities, as follows: (1) wood; (2) steel; (3) wood and steel; (4) concrete; (5) hollow tile; (6) other fireproof types; (7) concrete in combination with any or all of these, as wood, steel, or tile frame with concrete finish and floors; (8) brick or stone, either alone or in combination.

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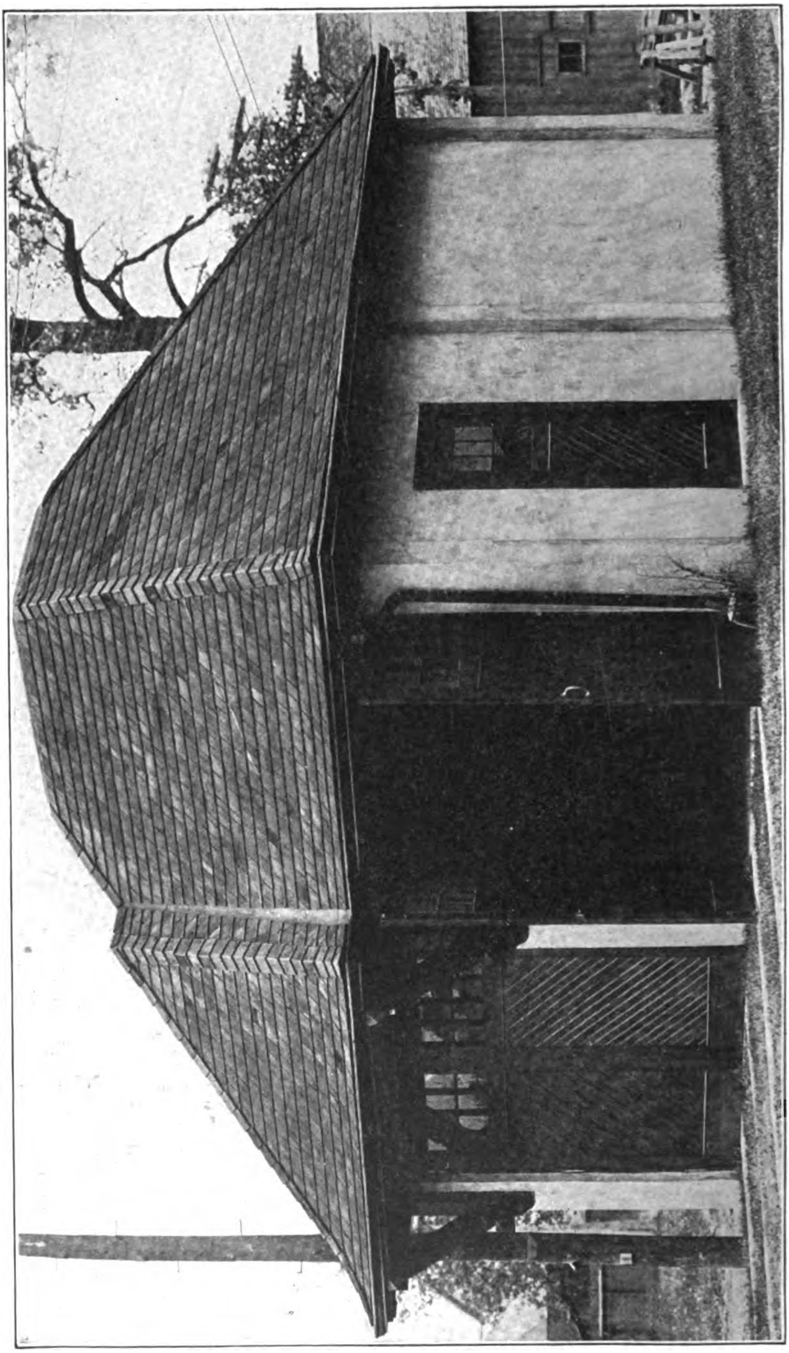

Fig. 1. Concrete, Metal Lath, and Wood Garage. A Good Example of Semi-Fireproof Construction

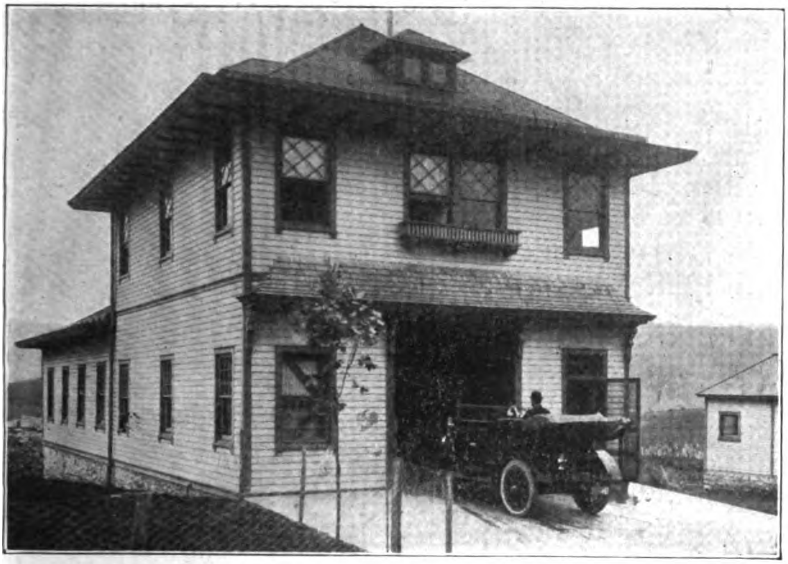

Fig. 2. All-Wood Garage with Living Accommodations for Chauffeur

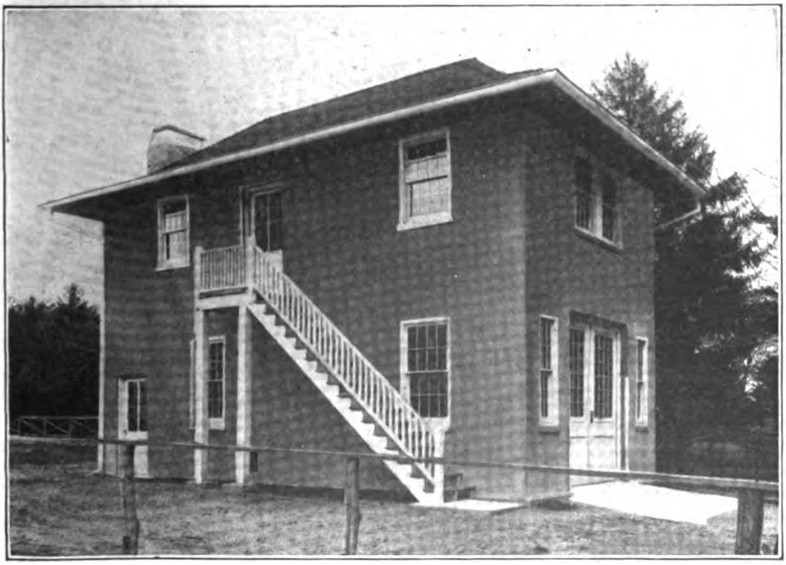

Fig. 3. Hollow Tile and Cement Garage

Doubtless the majority of garages to be considered will come under 1, 4, 7, or 8, but they all represent rather distinct types. For instance, Fig. 1 has a sheet metal (metal lath on steel angles) framework with a smooth concrete plaster covering, while the floor and runway are of cement, and the roof of shingles on wood framing. This represents the semi-fireproof type, walls and floor being strictly fireproof, while doors, window frames, and roof would burn readily. As such, the insurance rates would be much higher than on an all-concrete structure.

In Fig. 2 is shown a garage which is all wood except for the floor and runway, the latter extending the full width of the building in front. The forward portion of the garage is carried up a second story for the chauffeur and his family. The building houses three large cars and is well equipped.

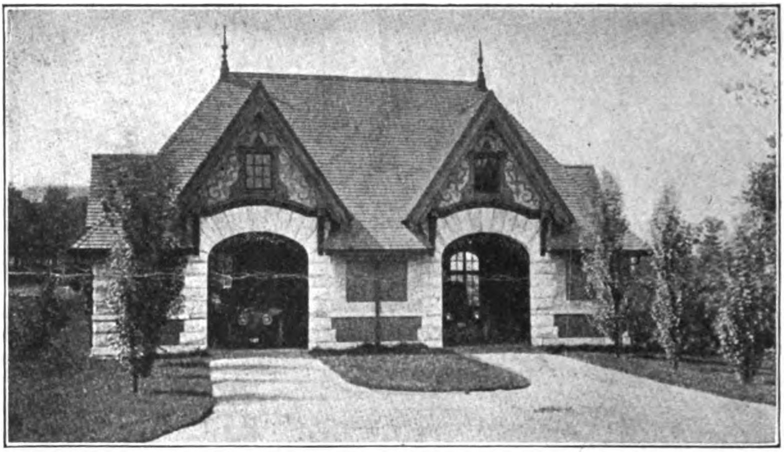

Fig. 4. Artistic Brick and Stone Garage

An example of hollow tile construction with a thin cement plaster covering is shown in Fig. 3. This holds two cars and provides living rooms on the second floor, similar to Fig. 2. Except for window frames, doors, stairs, and roof, this is fireproof, the hollow tile giving the additional benefit of greater warmth in winter and coolness in summer. As will be shown presently, this material may be used without an interior covering.

A few other types will be discussed briefly. Fig. 4 shows a brick building with very ornamental stone trimmings. This garage

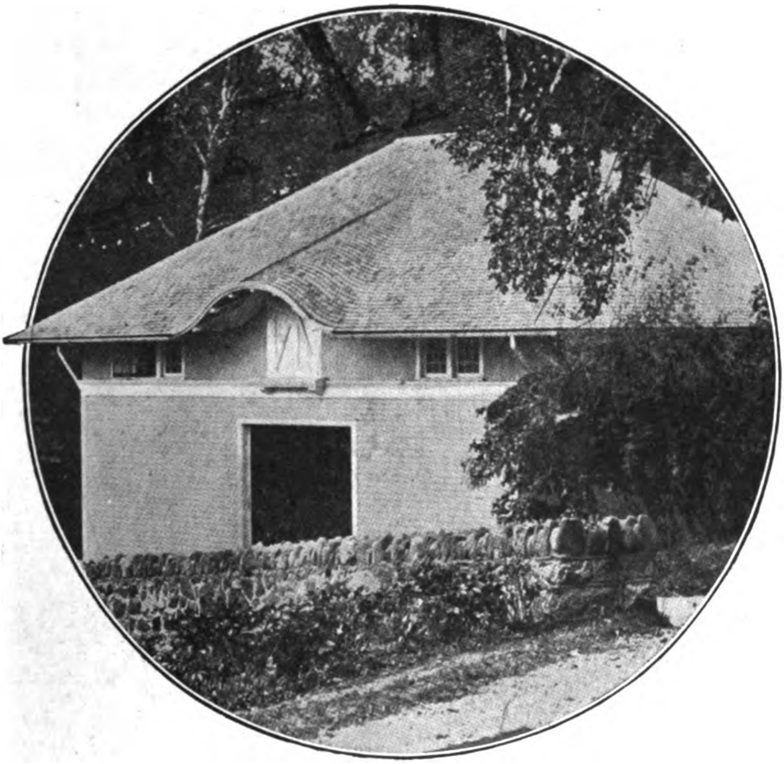

Fig. 5. All-Frame Garage for Two Cars

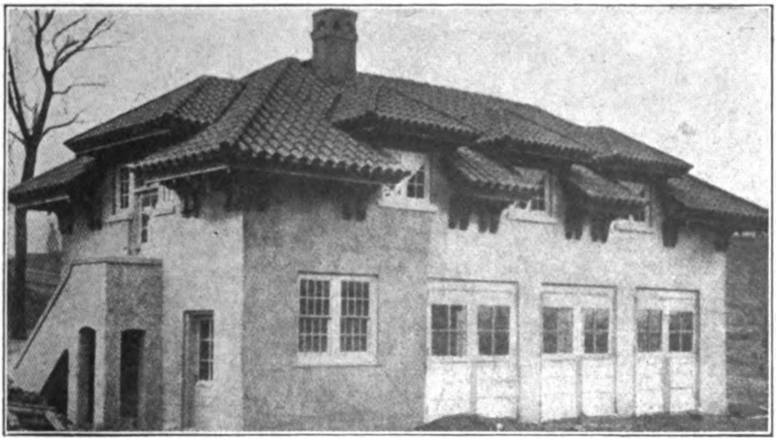

Fig. 6. Pretentious Concrete Garage with Tiled Roof

will house two or three cars and is provided with double doors to facilitate entrance and exit, always an important feature. Fig. 5 represents an all-frame structure, and Fig. 6 one of concrete with a tiled roof and holding three cars. Of all the types so far shown, this

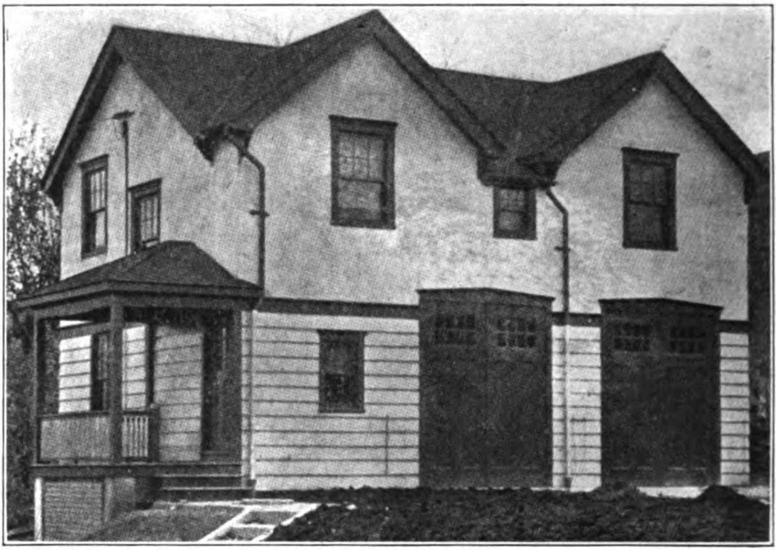

Fig. 7. Frame Garage with Plaster Second Story

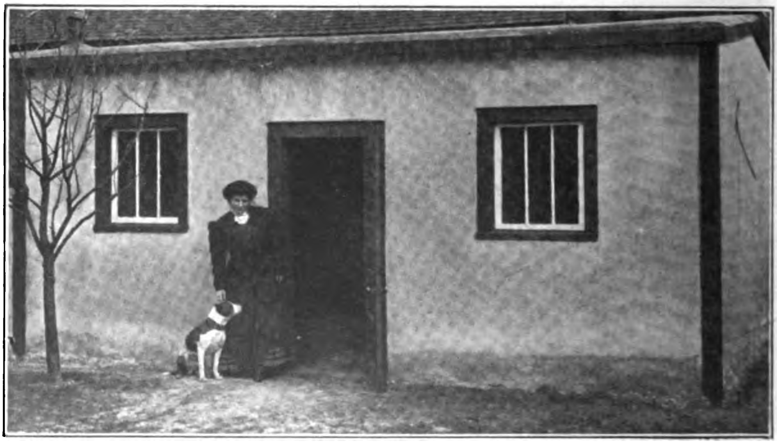

Fig. 8. Fireproof Garage with Concrete Roof

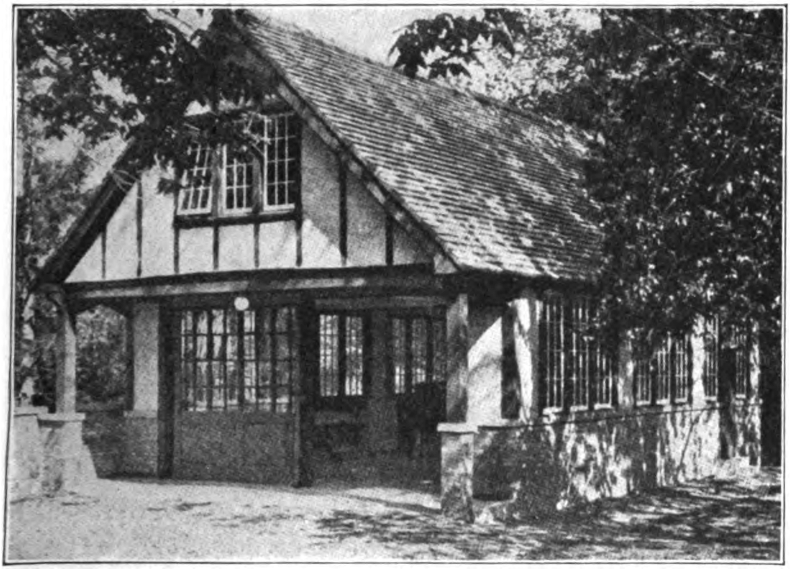

Fig. 9. Excellent Garage of Concrete and English Half Timbering

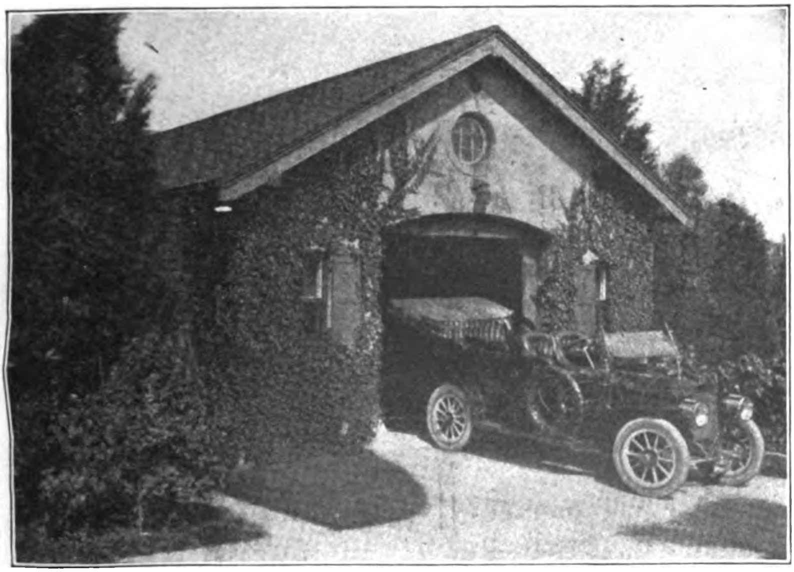

Fig. 10. Concrete Garage in Pretty Setting

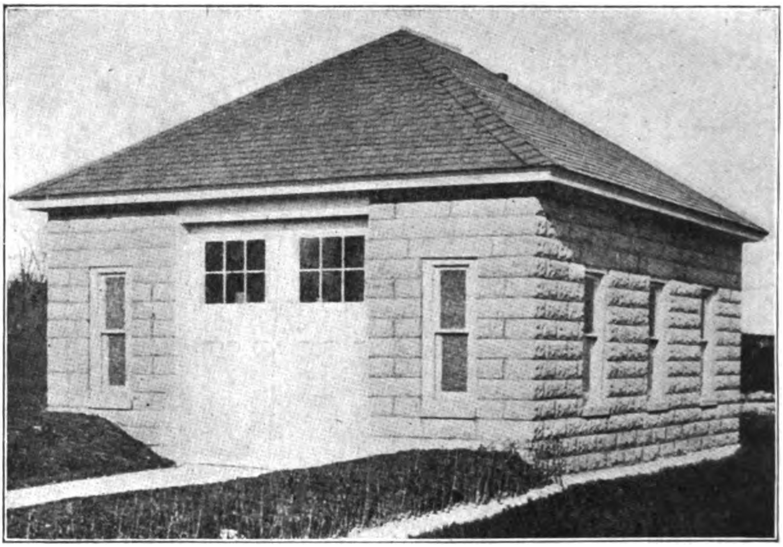

Fig. 11. Concrete Block Garage

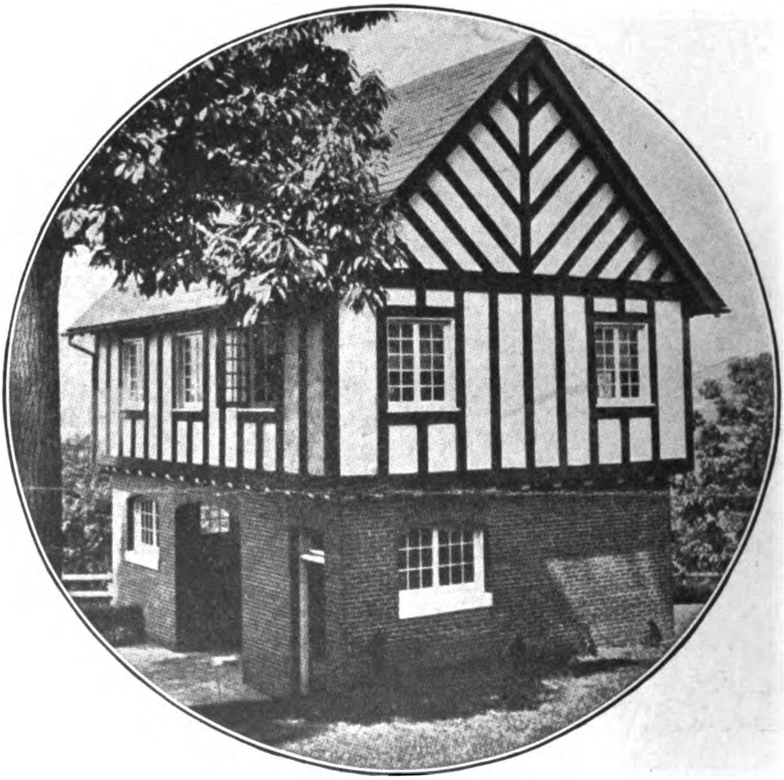

Fig. 12. Brick and Concrete Garage of Artistic Design

is the most nearly ideal from the point of view of fire hazard. Fig. 7 shows an ordinary frame structure with plaster second story which holds two cars. Fig. 8 shows a fireproof garage of concrete on metal lath, built on the Kahn system, the roof as well as the side walls being of concrete. Fig. 9 illustrates the combination of stucco plastering and English half timbering with a concrete and stone foundation wall. Architecturally this is as pleasing in appearance as

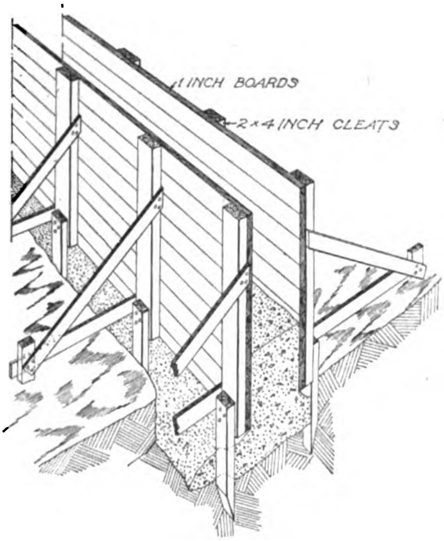

Fig. 13. Construction of a Concrete Form

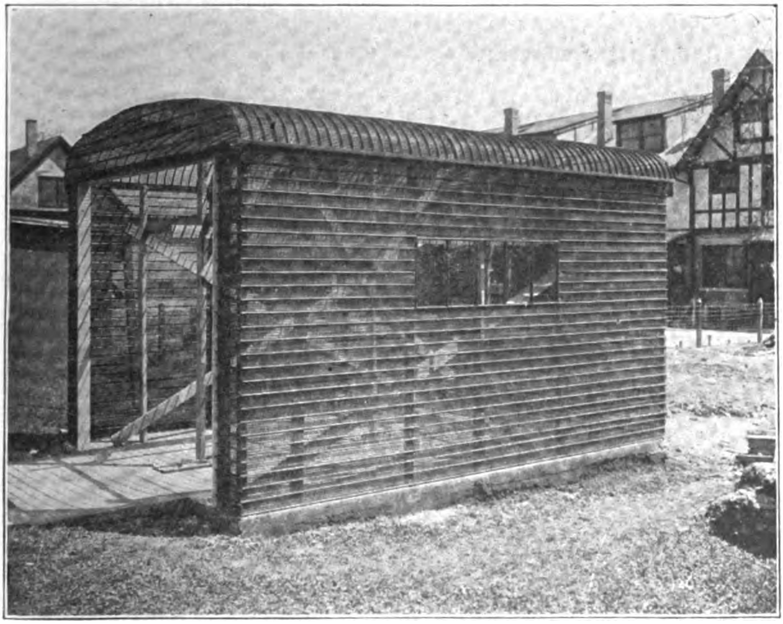

Fig. 14. Metal Lath Frame Prepared for Concrete Garage

any shown. Fig. 10 is of concrete, Fig. 11 is of the same material in block form, while Fig. 12 has a brick first floor and stucco plaster over wood for the second.

Concrete being considered the best material for garage construction, a few words in detail will not be out of place. Concrete may be used either as a plaster over steel or other structure, the thickness of this layer varying with conditions from 1 inch up to 3, or it may be moulded in forms and allowed to set, in the latter case the thickness required being as high as 18 inches.

When used in forms, as many of the latter must be built as the workmen can fill with semi-liquid concrete at one time. Fig. 13 gives the details of such a form, one end being left open to show the foundation and wall thicknesses. Smooth boards must be used, otherwise the resulting wall will be rough.

When metal lath is used on a structural iron framework, Fig. 14, the concrete is laid on like plaster. The illustration shows what can be done for less than $200 including the contractor's profit, the cost of each individual item being given below. The floor plans and arrangement will be presented and discussed later.

Cost of a One-Car Concrete-on-Metal-Lath Garage

568 sq. ft. of No. 24 gauge lath at 6 cents per foot	$34.00
535 pounds of structural steel at 5 cents per pound, ready for erection	26.75
3 windows, with 12×20 glass 1 light high, 5 wide	14.00
Total materials cost	$74.75
Floor 3 inches concrete, 1 inch finish	$16.80
Erection of structural steel and Hy-Rib, labor only	15.00
Wall plastering, 2 inches thick, roof 2½ inches	65.00
Door, 1¾ inches thick, including hanging and hardware	20.40
Glass and glazing	2.80
Total work and accessories cost	$120.00
Grand total of entire building, including contractor's profit	$194 75

The interior of the hollow tile garage, which is shown complete in Fig. 3, is brought out in Fig. 15, the wall surface being formed by the tile themselves, without the aid of plaster. In the foreground may be seen the drain, while just above it will be noted the washer and the electric lights. This building shows an important advan-

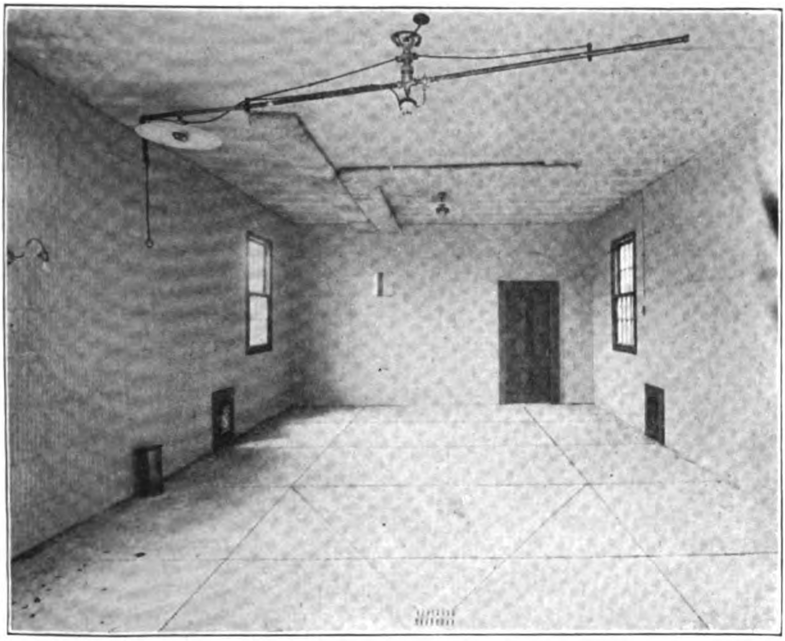

Fig. 15. Interior of Fig. 3 Showing Plain Tile Finish

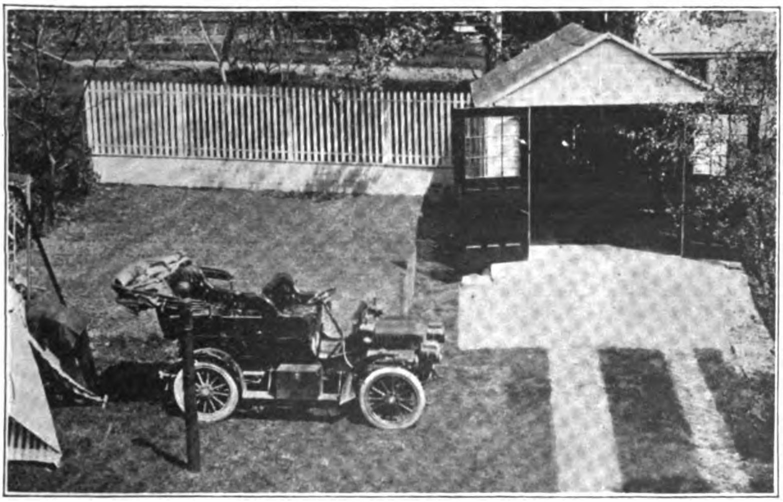

Fig. 16. Convenient Back-Lot Garage of Simple Construction

tage in garage construction, namely, the superior utility of length as compared with width.

One-Car Designs in Detail. *Long Type.* The majority of garages are of the one-car type, although occasionally it happens that neighbors get together and build a common structure, or else one man builds large enough for three or four, and rents space to his neighbors. Fig. 16 shows what may be done with the back of an ordinary suburban lot. Here a small garage of wood has been erected at the extreme rear, with a washing platform and runways of cement, the whole being surrounded in a pleasing manner by vines and trees. While the building is not large it saves the owner many a long walk to and from the nearest public garage as well as considerable money in the course of a year.

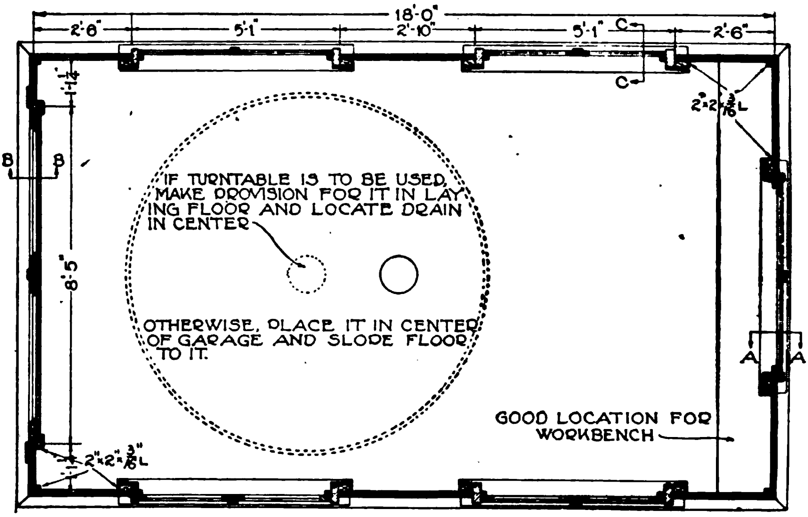
18'-0"
2'-6"
5'-1"
2'-10"
5'-1"
C
C
2'-6"
1'-1½"
2"×2"×3/16"L
B
B
8'-5"
IF TURNTABLE IS TO BE USED, MAKE PROVISION FOR IT IN LAYING FLOOR AND LOCATE DRAIN IN CENTER
OTHERWISE, PLACE IT IN CENTER OF GARAGE AND SLOPE FLOOR TO IT.
A
A
GOOD LOCATION FOR WORKBENCH
2"×2"×3/16"L

Fig. 17. Floor Plan of a Garage Showing Turntable

It will be noted that its size will allow only room for the car and for a passageway 2 feet wide on each side. Such a scant amount of space is seldom advisable if the owner figures on doing his own work, in which case the design should include a well-located workbench and a full stock of tools. The floor plan shown in Fig. 17 really represents the plan of Fig. 8 and of Fig. 14 slightly modified. In this drawing the writer has included an extra window on each of the long sides, making this change because of the large number of garages he has seen which were planned with too little light. As a matter of fact, when the car is in the building and is blocking off the big double doors at the front, and usually the one side window also, some unobstructed window light is absolutely necessary.

A workbench has been included at the rear end, with a large window over its middle, and a turntable near the center of the floor. The floor space of this garage is sufficient to allow turning a car, so that it may be driven in front end first, and then turned around so as to leave in the same manner. The frequent accidents caused by backing out or into the building are thus avoided, and washing and repair work are made much easier.

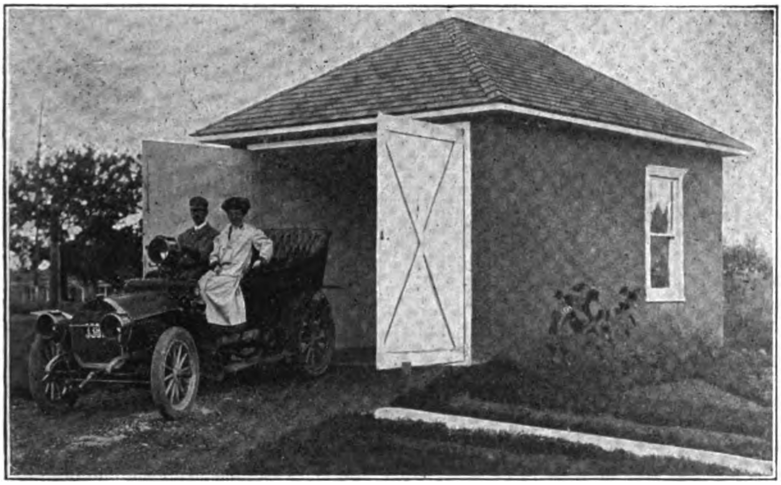

Fig. 18. Square Type of Garage of Concrete Construction

Square Type. The neat little concrete garage shown in Fig. 18 is more nearly square in shape than those already shown. This brings up the question whether the square or the long type of equivalent area is preferable. Some hold that the short, nearly square shape presents the most advantages, since everything is close together; others believe that the long, narrow shape has many advantages over the square form.

For this reason two sketches of typical floor layouts, Figs. 19 and 20, have been prepared. The former measures 17 × 18 feet, and its inside area about 283 square feet, while the latter, measuring 14×22 feet 6 inches, has about 295 square feet of floor area inside, a difference of about 4 per cent. At a glance the longer one shows more working space, although, to be perfectly fair to the square type on this point, the turntable in Fig. 19 should be as close to the front door as in Fig. 20.

As to window space the two types are about equal, the extra back window and the two small front windows in the square type being offset by the larger number of windows which can be used on the sides of the long type. When working on a dismantled car, however, for occasional repairs or during the spring and fall overhaul, the design of Fig. 20 gives more open area at the back, clearer bench room, and freer window space.

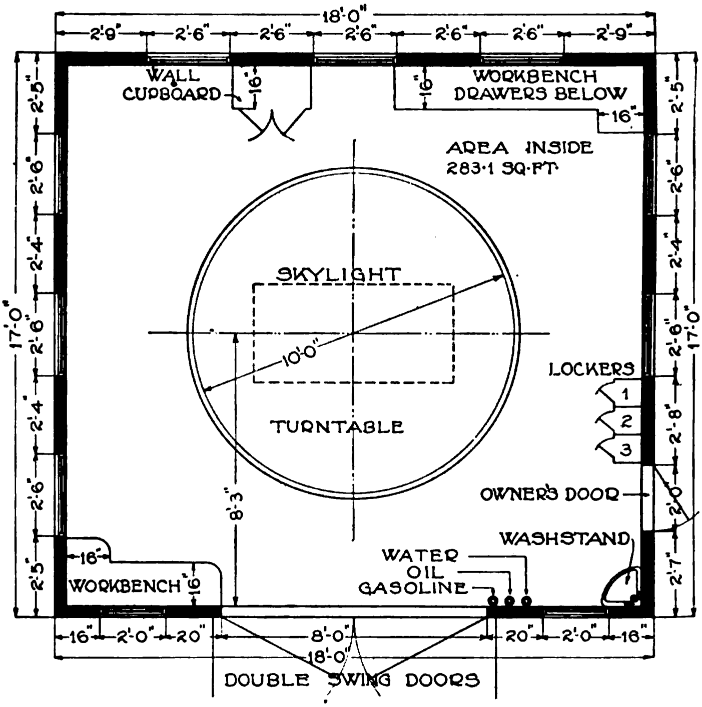

Fig. 19. Floor Plan of Square Type of Garage

Portable Form. It would not be quite fair to dismiss the one-car garages without mention of the portable form. This type, an excellent specimen of which is shown in Fig. 21, has the attractive feature to the busy man of being sold ready for use by its makers. The one shown is 12×18 feet inside, and is made in sections. To the man who does not own his home, it solves one highly important point—that of the disposition of his building should he move. A portable garage is simply dismantled and erected at the new quarters, none the worse for the change.

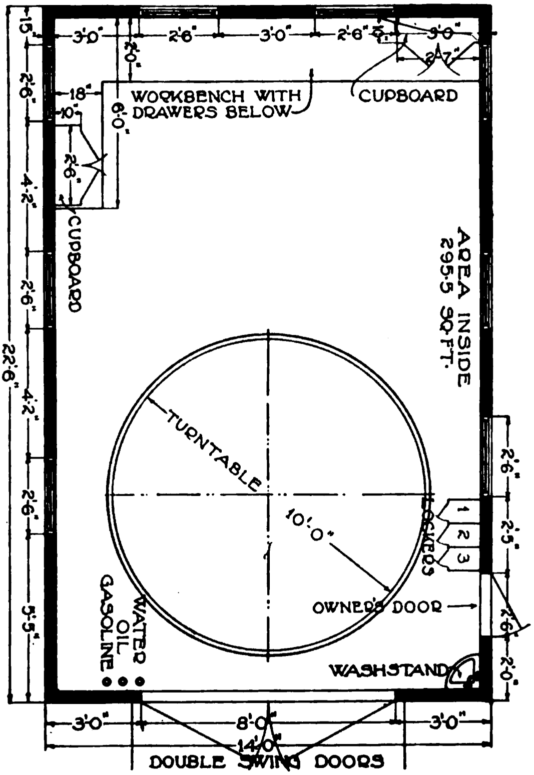

Fig. 20. Floor Plan of Long Type of Garage

Two- and Three-Car Designs. Turning next to the garages which are built primarily for two or more cars, and which in the main are more commodious and better appointed throughout, there enters for the first time the consideration of the quarters for the driver and his family. Sometimes, although the construction of the building may be very elaborate, the element of convenience and adaptability has often been ignored entirely. Such, for instance, is the garage shown in Fig. 22, the plans for which may be seen in Fig. 23. The building is two stories high, the second being given over to living rooms entirely. Even on the first floor, the coal storage, furnace, storeroom, entry, stairs, and charging room for batteries take up more than one quarter, so that, of the total area, the cars have less than three eighths. In considering this design, it will be noted that aside from the double front doors, there is little provision for light. The car room, measuring 25×30 feet—that is, 750 square feet—has only four windows, all small and all at one end. The rear of this room has no windows, nor has the repair room, with its pit, any light except when the doors to the store and charging rooms are left open. A better arrangement could have been effected by placing the coal and charging rooms in the center and the repair room with pit on the corner.

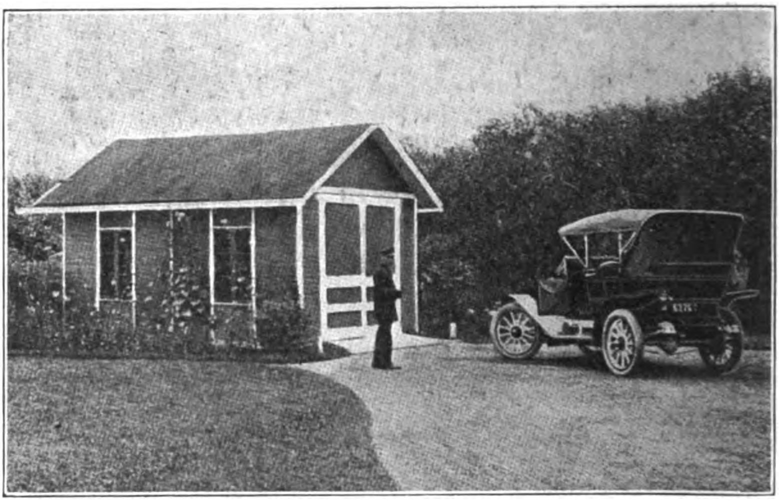

Fig. 21. Portable Type of Garage

Almost as bad in this respect is the English garage, Fig. 24. where three tiny end windows, over 40 feet apart, and as many skylights some 20 feet in the air, are depended upon to illuminate the whole interior of a building measuring 30×46 feet. This garage has steel roller blinds for the entering doors, so that with these closed no light can be expected from that side as might be the case with wood paneled and glass forms.

An improvement over both may be seen in Fig. 25 which is of field-stone construction. Although it houses but two cars, it is sufficiently large for three, having interior dimensions of 20×30 feet. The interior has a wash stand and lockers at the entrance on the right. At the back, on the same side, are a forge, anvil, drill press,

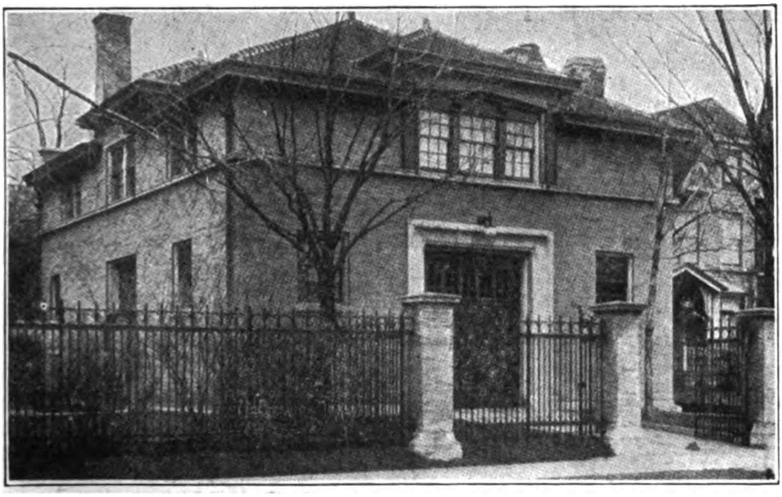

Fig. 22. Example of Pretentious Private Garage with Bad Interior Design

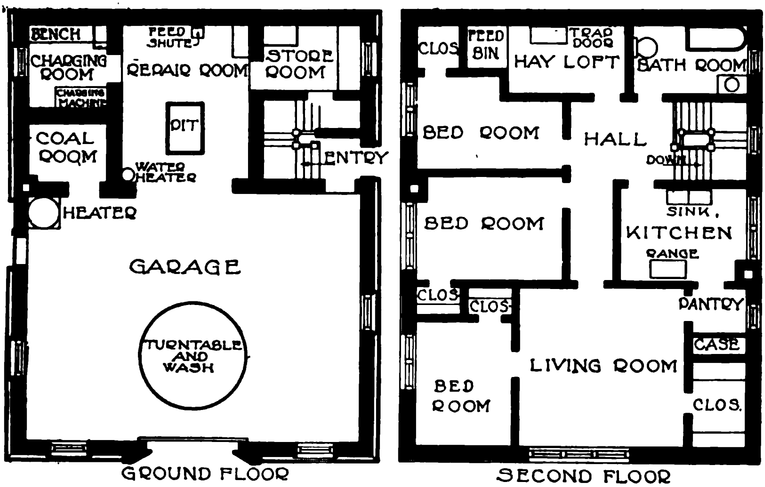

Fig. 23. Floor Plans of Garage Shown in Fig. 22

and other tools. In the middle of the rear side is a large fireplace, while the entire left side is taken up with a wide workbench which

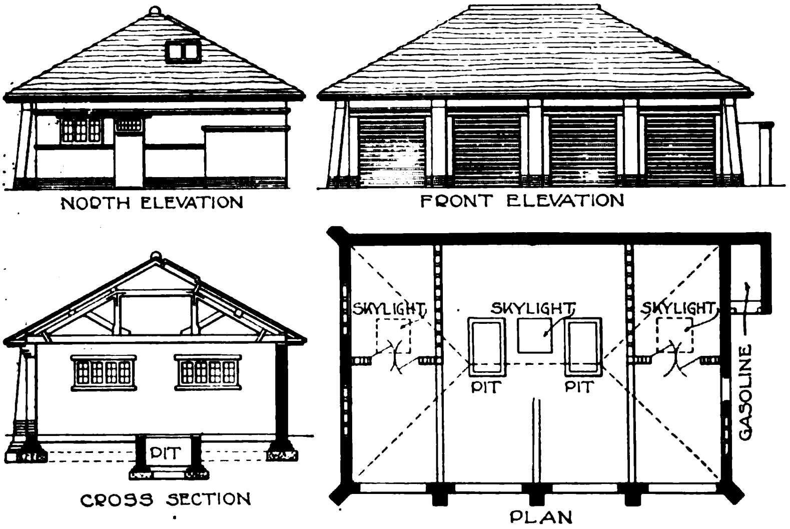

Fig. 24. English Garage with Inadequate Lighting Facilities

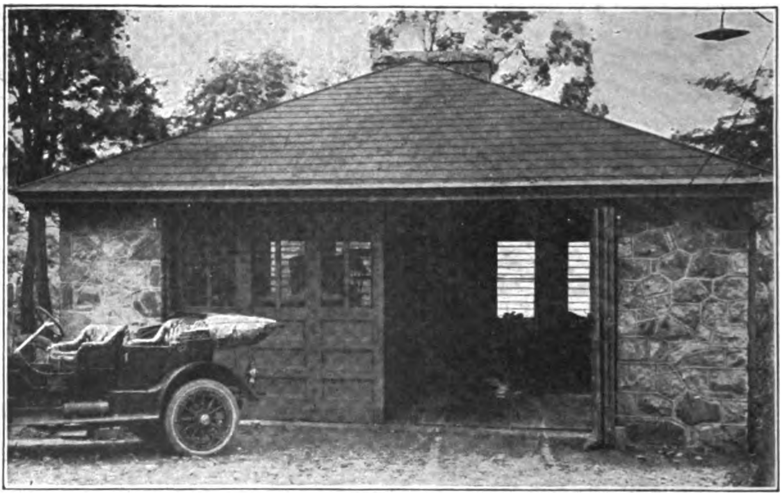

Fig. 25. Stone Garage of Good Construction

runs from front to rear. The doors are double, each half folding up into three sections. When all are folded back, practically the entire front of the building is open. For lighting there are four rear windows, which are visible, and two on each side, while it will be noted every section of the doors carries a large pane of glass.

A design of a one-story garage having chauffeur's quarters has already been shown in Fig. 10. The ground plan is shown in Fig. 26. This is large enough for two cars, a big workshop being provided in one rear corner where there is plenty of room and light, while the size of the building allows of a very comfortable home for a single driver. Entrance is by double door, with place for washing both cars at once. Near the door is placed a supply of water for filling the radiator, and also the gasoline and oil supply pipes. In case repairs are needed, it is possible to drive directly into the workshop, over the pit, and start work on the car immediately. Where any work must be done under a car, either a pit or a substitute for one is a necessity.

General Equipment. In the planning of the general equipment of a garage considerable stress should be laid upon lighting, heating, ventilation, water supply, drainage, and similar items.

Lighting. The necessity for plenty of window space has been dwelt upon at some length in individual cases already discussed, so nothing more need be said except that it is impossible to get a garage interior too well lighted. In fact, were it not for the matter of warmth in winter, it would be advisable to build the walls or at least the roof of glass. Skylights are excellent, the light from above appearing to have more illuminating power than that from windows, in addition to which it is more difficult to cut it off. In the way of artificial illumination, electricity is the preferable form, since gas, kerosene, and practically all other lamps, present an open flame, which, in the case of a gasoline leak, may cause an explosion.

Heating. Heating is generally neglected, but the man who has overlooked it and then been obliged to work on the car for several hours during a winter day, will agree that this equipment is important, even though it be only a couple of portable oil stoves. Any kind of stove with open flame is dangerous, however, where so much gasoline, oil, and other highly inflammable materials are handled, hence the source of heat should be either steam, hot water, or hot air, with the fire located outside of the building, or else partitioned off from the main garage.

Ventilation. Ventilation is doubly important in a garage for,

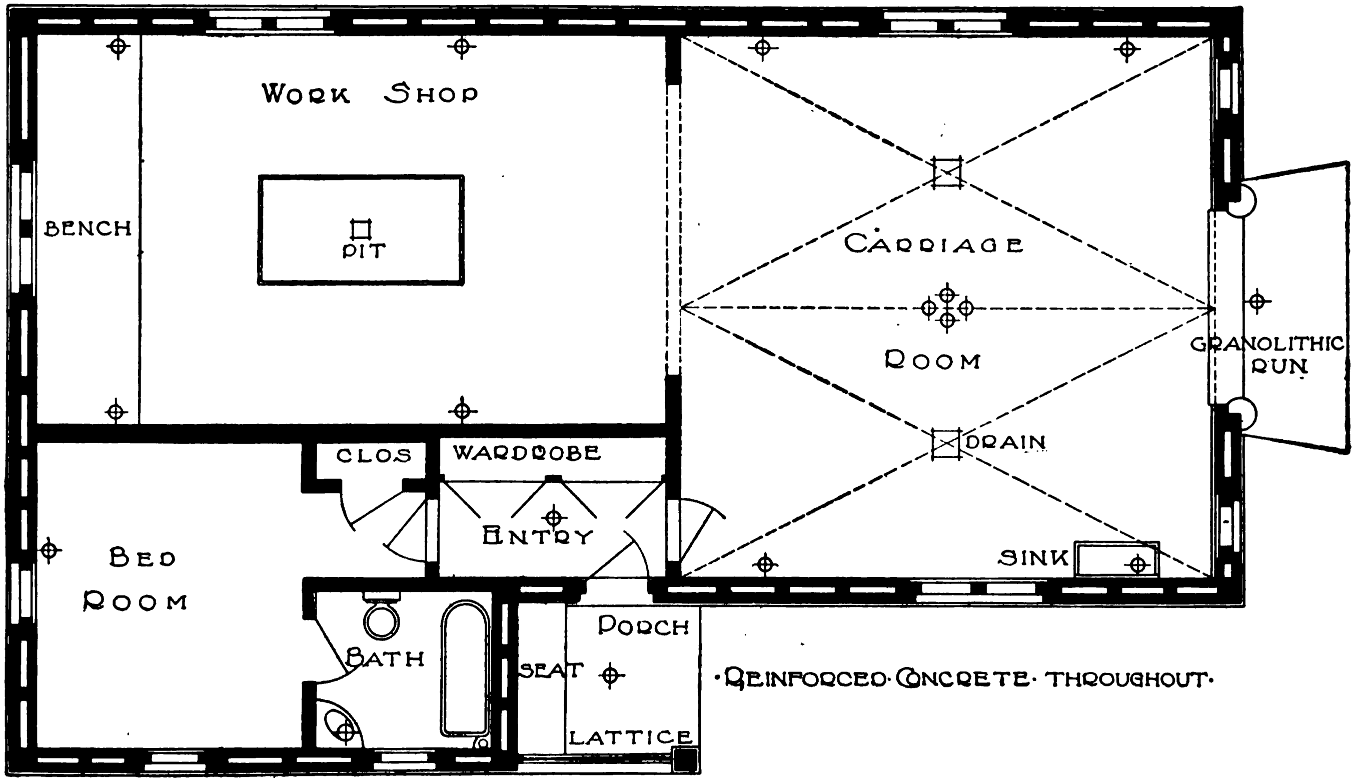

Fig. 26. Floor Plan of Garage Shown in Fig. 10

despite the fact that gasoline liquid is very light, its vapor is heavier than air. The vapor, therefore, falls instead of rises, as one might suppose and the inflammable fumes lying along the floor as the result of spilled fuel are a source of danger for a long time. A garage should always have two openings for ventilation, one placed near the ceiling or roof, and the other close to the floor. This will take care of all possible cases, and if the openings are made large enough, a constant draft will be maintained which will keep the air inside pure and free from all dangerous gases.

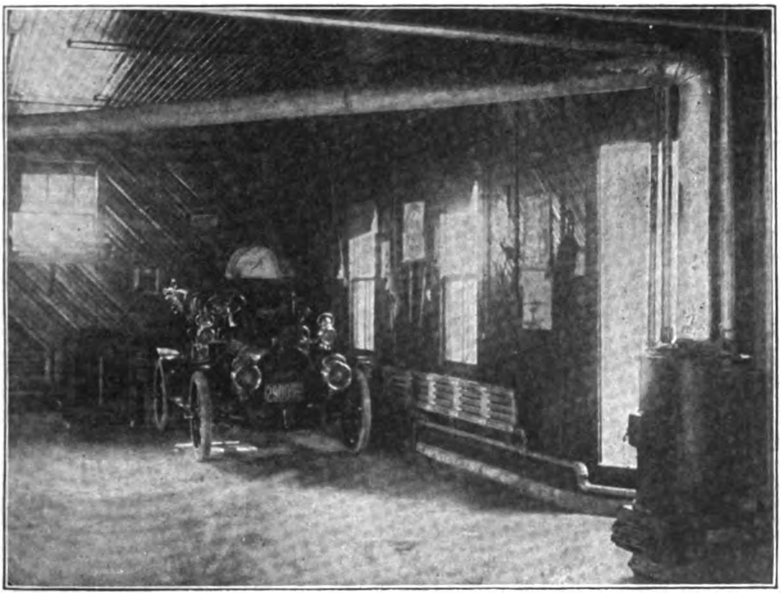

Fig. 27. Heating Arrangement in Garage

Water Supply. Water supply in the city is no problem at all, simply a matter of running a pipe from the house to the garage with a suitable faucet, but in suburban or country places, it is not always as simple. Wherever possible, there should be at least two connections for running water within the building, one for washing purposes, and the other for general use. In addition, it is well to provide a method of heating water for use in winter. If the car be used the year round, as is usually the case, it is decidedly inconvenient to wash it with cold water during the months of December and January.

This convenience may be provided in conjunction with the heating system for the building, Fig. 27 showing a furnace which supplies hot water to a series of radiators arranged upon the walls, comparatively close to the floor, as well as to the overhead washer. The result is that the owner has not only a comfortable place to work at all times, but a car which is well kept.

Drainage. The matter of drainage should have early attention. A proper drain is one which will pass the water and other liquids out to the sewer but will retain the more inflammable gasoline. This separation is effected through the ability of gasoline to float upon water and other heavy liquids. As in the form shown in Fig. 28, the outlet is covered by a depth of water, which acts as a water seal. The open space above the liquids, on the other hand, is connected by means of a vent pipe to the roof or other place where the gases which form may pass off harmlessly. When the water accumulates to the depth of the outlet, a quantity will siphon off from the bottom, not the top. As soon as the lower edge of the vertical partition is reached, air will enter, the flow will stop, and the gasoline will remain in the drain.

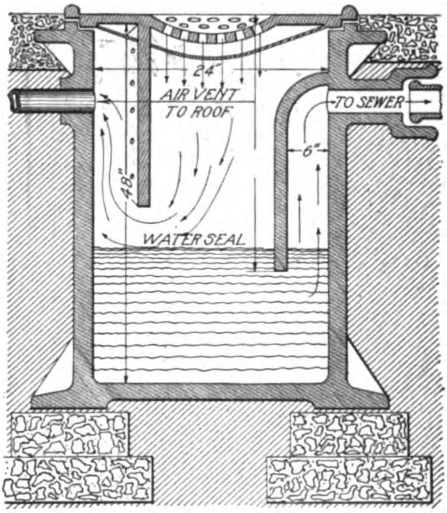

Fig. 28. Details of Proper Drain for Garage

Source of Power. In constructing a large garage, it is well to consider the subject of power, and make some provision for it. This may be done by suspending an induction motor from the ceiling, belting it to a line shaft, suspended from the same, with suitable belts and countershafts for the individual tools. If the house is of concrete, bolts may be set into the ceiling at the time of building, even though no immediate use for them is planned, thus saving a great amount of work later.

Oil and Gasoline. Little need be said of the handling of oils and gasoline, since it is now so generally understood that the only way to handle either gasoline or oil is by means of tanks. When everything is considered it will be found more economical, more safe, and more convenient, to purchase some well-known system in the desired size.

For those who desire to install their own system the following is suggested: A seamless steel tank *C* with three outlets, one large for filling purposes, and buried in the ground about as shown in Fig. 29, should be obtained. Next a supply of galvanized iron pipe of comparatively small diameter should be secured and attached to the tank. The two pipes proceed, one pipe *D* from the bottom of the tank into the building, and up to such a height *E* as would be convenient for drawing off the fuel; the other pipe *B* runs from the top of the tank to a source of compressed air, such as may be supplied by an old bicycle pump *A*. When there is fuel in the buried container, it is only necessary to open the air cock and pump a little on the foot pump. The pressure in the tank will then force out the fuel at the other pipe when the cock *E* is opened. When not in use, both cocks should be closed. The tank should be buried below the frost line and the filling cap *F* should be so arranged that it can be locked.

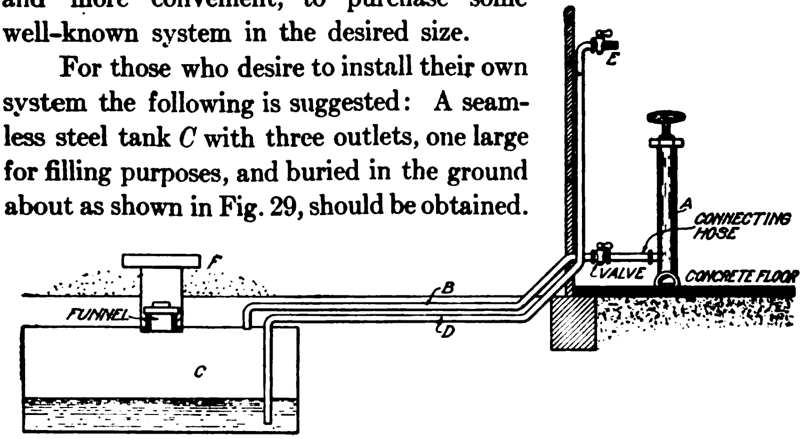

Fig. 29. Arrangement for Outside Fuel Tank

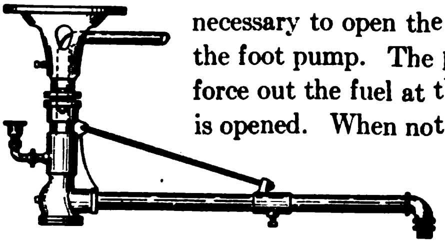

Fig. 30. Ceiling Washing Appliance

Washing Apparatus. An overhead washer is admitted to be the best form and one which can be easily made as shown in Fig. 30. This is constructed from ordinary water pipe, preferably galvanized, and various standard fittings, only two special fittings being needed, viz, a swivel joint, without which the apparatus could not turn, and a special fitting to which the brace is attached. The top portion is only a form of protective hanger, inside of which the feed pipe is attached by an elbow joint, to which the vertical member is screwed. The whole arrangement is susceptible of considerable simplification, even over that illustrated.

Turntable. One of the drawbacks of the small building has previously been mentioned, viz, the necessity for backing the car in or out. This may be avoided by installing a turntable, the car being turned around on this, so as to enter and leave facing forward. An excellent form of turntable is shown in Fig. 31. The turning portion is mounted on a central row of very large balls, supported on a raceway. Farther out are set eight rollers, upon which the table will roll if the load is not exactly balanced. When properly balanced the whole may be turned on the balls with little or no effort.

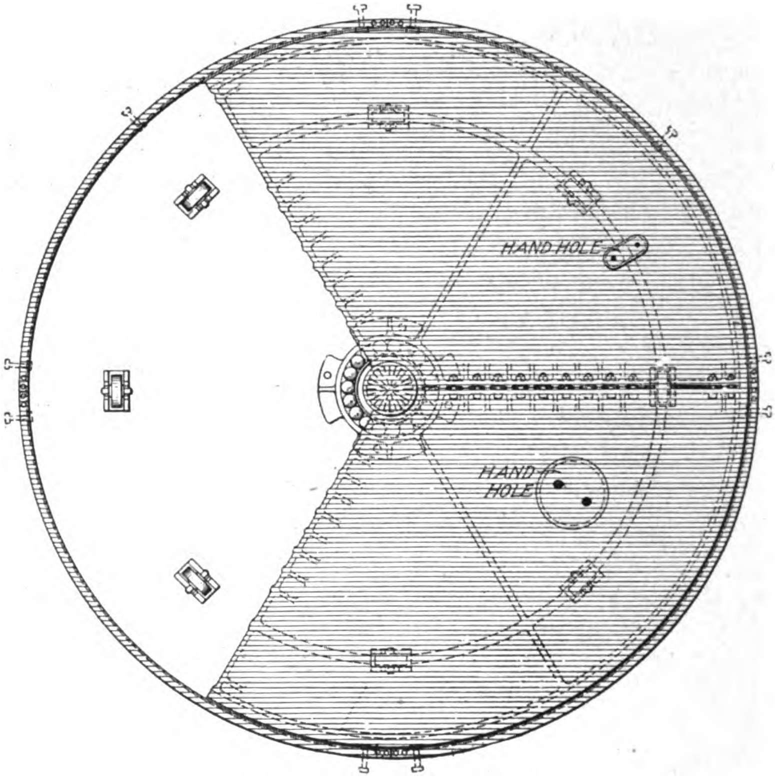

Fig. 31. Garage Turntable

There are numerous advantages of a turntable other than turning the car around, for example, it allows a greater amount of floor area to be utilized; it facilitates the handling of the machine when washing; and it enables one to easily turn the car so as to get the best light on a particular part which needs repair.

Supply Cabinet. One of the things to be learned at the outset is that the automobile has from 2,000 to 3,000 separate and distinct parts and that if these are spread about promiscuously they will doubtless get mixed up, mislaid, or lost. To avoid this occurrence, a systematic and orderly method must be followed, as, for instance, the use of boxes for all parts which are removed, each properly marked, and for the smaller units, a cabinet like that shown in Fig. 32. The latter is a small cabinet of octagonal shape, pivoted on a central spindle so that it may be turned. A total of 96 compartments are available for the smaller parts, as well as for screws of the various sizes, nuts, bolts, cap screws, cotter pins, lock washers, and the innumerable odds and ends which accumulate as time goes on and which so often furnish the one thing needful to the desperate repair man at the proper moment.

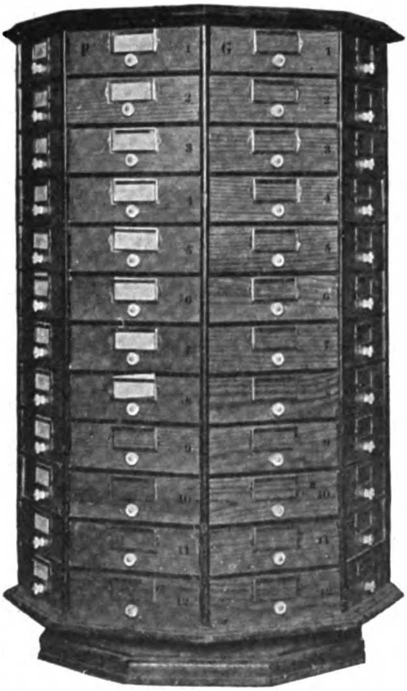

Fig. 32. Useful Revolving Cabinet

Tools. In planning his garage the car owner should not forget that there is something to be done besides build the house. The equipment of small and machine tools should be fairly complete if the maximum saving in repair charges is to be made. It will be wise, therefore, at the outset to have a very close estimate of cost made for building alone, and then apportion the balance of the available funds to tools and equipment, calling upon some experienced friend for a list of requisite tools, and obtaining an estimate of their cost from a supply house. Many men have divided the available money in two equal parts, one for the building, the other for its equipment. Although this seems like an extreme, the tools are certainly necessary and do not come with the car. For example, the list should include vulcanizer, power air-pump, set of drills, taps, reamers, set of wrenches, wheel pullers, set of files, voltmeter, ammeter, hydrometers, drip pans, funnels, waste and waste cans, gasoline and oil storage tank, tire and rubber tools and supplies other than vulcanizer, hack saw and blades, various punches, chisels, scrapers, wrenches, pliers, screw drivers, and valve lifters.

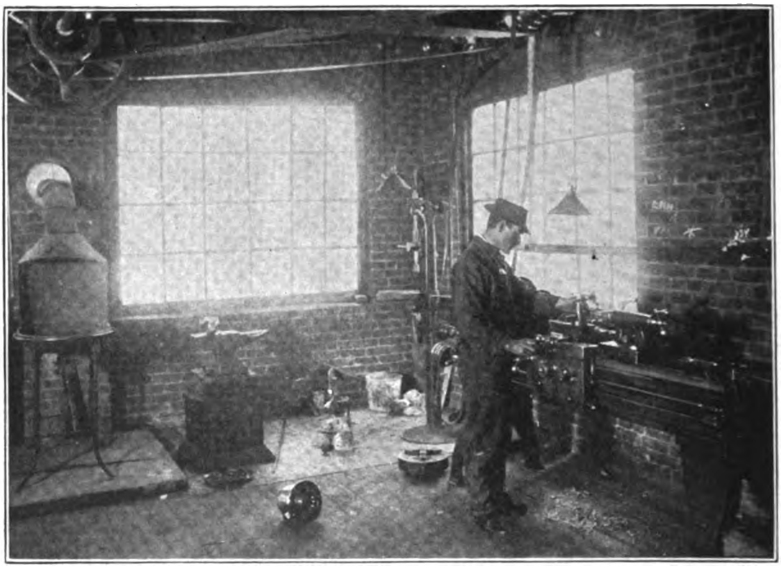

Fig. 33. Machine Shop a Necessary Feature of the Garage

If one is limited as to funds, he has the choice of spending it all on the garage and buying no tools immediately, but laying in a supply gradually later on as the necessity for them arises, or of dividing the money between the garage and tools in some such ratio as will enable the handling of repairs right from the start. The writer favors the latter plan, with the division about 75 per cent for garage and 25 per cent for tools.

Mention has been made of the provision of a power motor and shafting for running such machine tools as would be useful or necessary in a small shop. Fig. 33 represents a good arrangement of tools, including lath, drill press, forge and anvil. With this fairly inexpensive combination, any small job on the ordinary machine can be handled with pleasure and profit.

Considerable diffidence is felt about advice on the subject of small tools, because of the wide divergence of ideas on this subject. Some amateur owners have upwards of 200 tools while others get along and keep the car in repair and good running order with 20. Each man must decide in which class he belongs and purchase his tools accordingly.

Below is given a list of tools and equipment as an example of what the owner of an old car considered necessary.

Tool and Material Equipment

Block and tackle	$ 3.50
Fire extinguisher	16.00
Wiring garage	10.50
Vulcanizer	20.00
Two jacks	6.50
Complete set of tools	15.00
Grease and oil gun	4.50
Rubber hose	7.50
Overalls and jacket	1.50
Drip pan, 3×3 feet	1.35
One piano dust brush	.75
Two whisk brooms	.75
One broom	.25
Camp stool	.50
Two-gallon can for oil	.30
Three 5-gallon cans for gasoline	1.50
One long stem oiler	.75
Three short stem oilers	.75
Bucket	.40
Pressure gauge (tires)	3.50
Large funnel	.50
Oil funnel	.50
Glass funnel	.35
Supply of porcelains	1.50
Two pieces of chamois	1.50
Large sheep's wool sponge	1.50
Box waste	1.00
Odds and ends	7.50
Total	$110.15

A full page of tools is shown in Fig. 34, from which the amateur worker may make his choice. The outfit should contain two hammers, one light to carry in the car, and a heavy one to have around

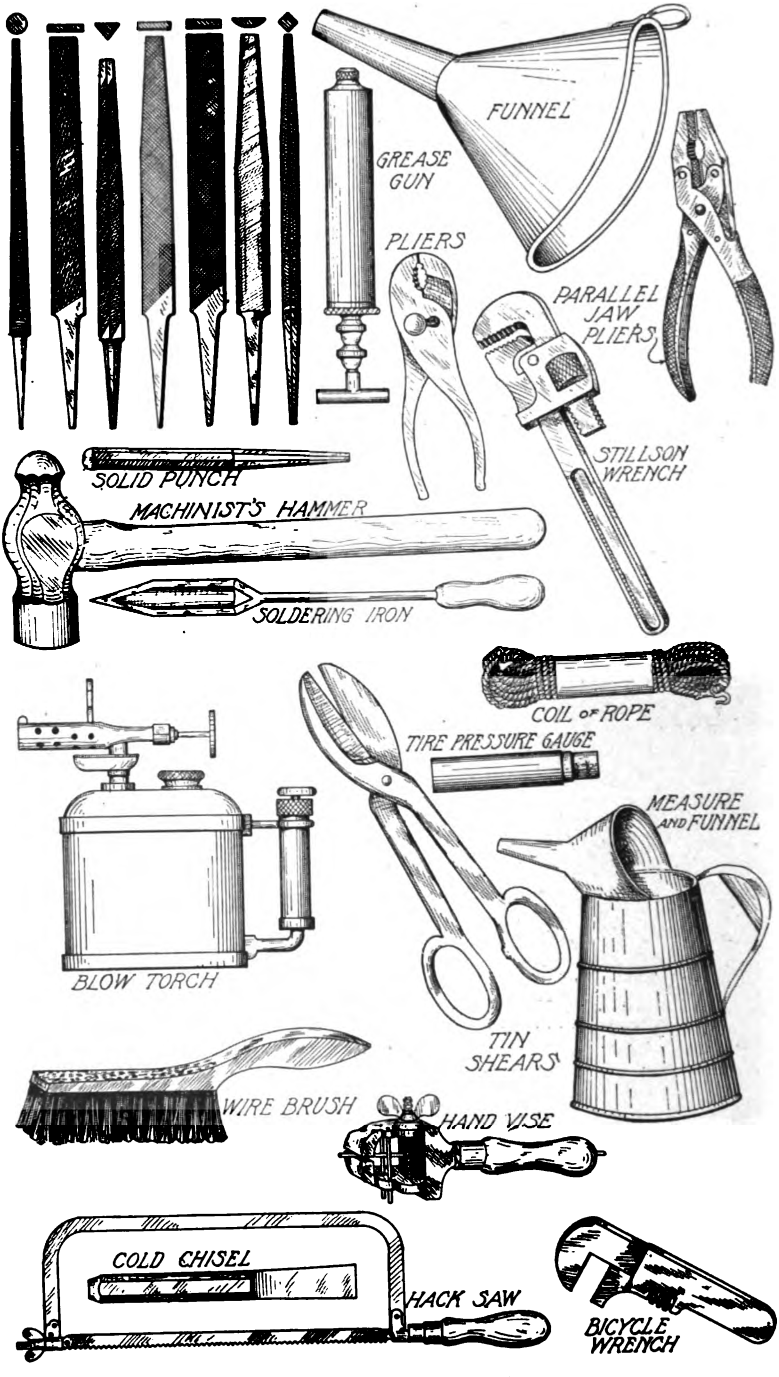

Fig. 34. Necessary Tools for Garage

the building; the set of files should be complete as to shape, grade, and size, those shown being for shape only; the hack saw is a hand tool, to be replaced by a power-driven affair if the work warrants it; and the torch is needed with the solder, and many times is useful in taking off stubborn nuts or bolts.

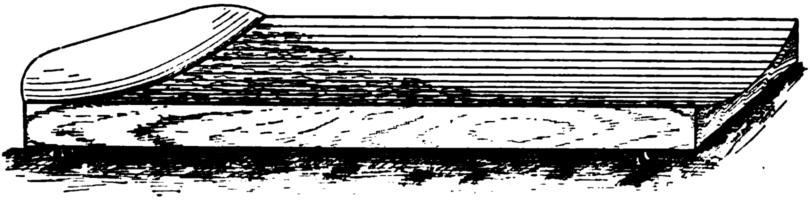

Fig. 35. Homemade Creeper

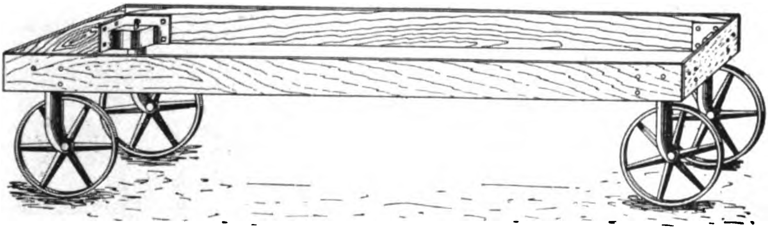

Fig. 36. Homemade Truck

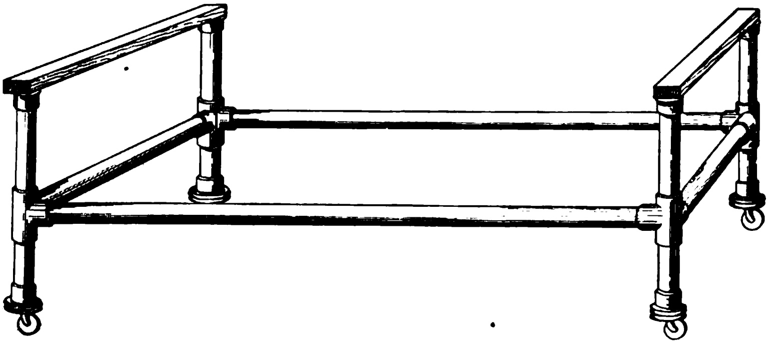

Fig. 37. Homemade Chassis Support

Homemade Equipment. There are a number of useful things in the tool line, which any one so disposed can make. Thus, for working under the car a creeper, Fig. 35, is almost a necessity unless the garage includes a pit or a substitute for it. The creeper consists of a wood frame with casters at the four corners and longitudinal slats as a floor. A pillow or rest may be made for the head if desired. Figs. 36 and 37 show a couple of stands which are useful in handling parts of the car when disassembling or reassembling it. Fig. 36 is heavier and is used for moving engines, transmissions, or axles around, while Fig. 37 is for holding a body while the chassis work is in progress.

Lifting heavy bodies to a considerable height by means of the small jack usually furnished with the car, is very laborious. To offset this, a quick-lifting jack may be made, as outlined in Fig. 38. This is nothing but a lever of the first class, which has a suitable base. The latter is made from a piece of 2×8-inch hard wood, into which are let a couple of 2×4-inch side pieces, preferably, also, of hard wood. The space between the uprights then would be 4 inches, into which should be fitted a long handle. It is evident that the longer the long arm is, compared to the short arm, the greater the weight which one man can lift. One which was seen in a public repair shop and garage was not less than 8 feet long, the forward projection being about 16 inches, which gave a five to one leverage. With this, one man would lift the whole rear end of a car from 6 to 10 inches in less time than it takes to tell it.

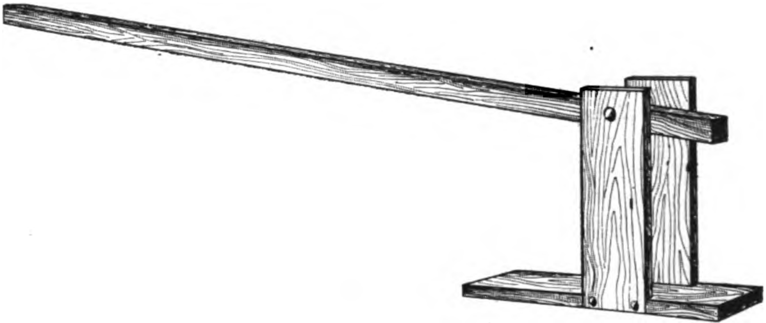

Fig. 38. Quick-Lifting Jack

The ingenious man will think of many similar time- and labor-saving contrivances which he can make. For example, the writer has found it an excellent idea to build four small but very sturdy sawhorses, two 14 inches and two 16 inches high, just high enough to allow the tires to clear the floor when these are placed under the axles. The use of these saves the time of the jack so much that they are in use practically all of the time.

Another good idea is a dark room or winter box for the tires.

This should be square, larger on each side than the tire diameter by, say, 2 inches, and in depth an inch or so more than four times the tire section; that is, for 30×3-inch tires, the dimensions should be 32 inches square and about 14 inches deep. This should be lined with a dark felt or some similar heavy material of dark color, and fitted with a hinged and locked cover. It should be placed in a dry place, or if this is not possible, should be set up on legs so as to raise it about 2½ feet off the floor.

General Instructions. In starting the work of disassembling the car, a few general rules should be laid down and rigidly followed. First, never remove a part whose location can possibly be mistaken, or which can be put back in a wrong position, without marking it. Second, always find out from a catalogue, instruction book, dealer, or friend, how a particular part is fastened on before trying to force it off. Third, do not get impatient if the piece does not loosen with the first application of force; try again and again. Fourth, use plenty of lubricant at all times, and don't be afraid to dip your hands into it; aside from washing off readily, it will actually make your hands softer.

The wisdom of the first caution is noted in the case of the timing gears, which must be in exact position relative to one another. If they are not already marked the car owner must do it, or else, when he comes to assemble, he will be obliged to go through the process of retiming, a long, tedious, and difficult job. A few minutes work with a hammer and prick punch will prevent this and insure exact timing. As to the second caution, if an attempt is made to pull off a gear, collar, or other part which is screwed on, but which the operator assumes is keyed or pinned, the part will probably be spoiled before the mistake is discovered, entailing extra expense and delay. Many times a gear is such a close fit on a shaft that it has to be heated to free it, even after all other fastenings have been removed. In a case of this sort, all the repair man can do is to be sure he is right, and then keep at it until it comes off. As soon as the refractory part has been started, a little lubricant should be squirted in, and the piece driven back to its former position. It will then start off a second time much easier and go farther. In similar ways, lubricant is as useful in disassembling as it is in running the car.

REPAIRS

Overhauling the Engine. By far the most important part of the car is the engine, and this should, therefore, receive the greater portion of the time and attention during any repair or overhaul work, going so far as to take it out of the chassis if the trouble is at all serious. For this purpose, all ignition wires and carbureter and magneto operating rods are detached. Next the various manifolds are removed, the water system is drained, and all hose connections are broken. Usually it is necessary also to take the radiator off, in which condition the appearance of the vehicle and the work is very much like that presented in Fig. 39, which shows two men busily engaged in loosening up certain parts of the engine preparatory to taking it out.

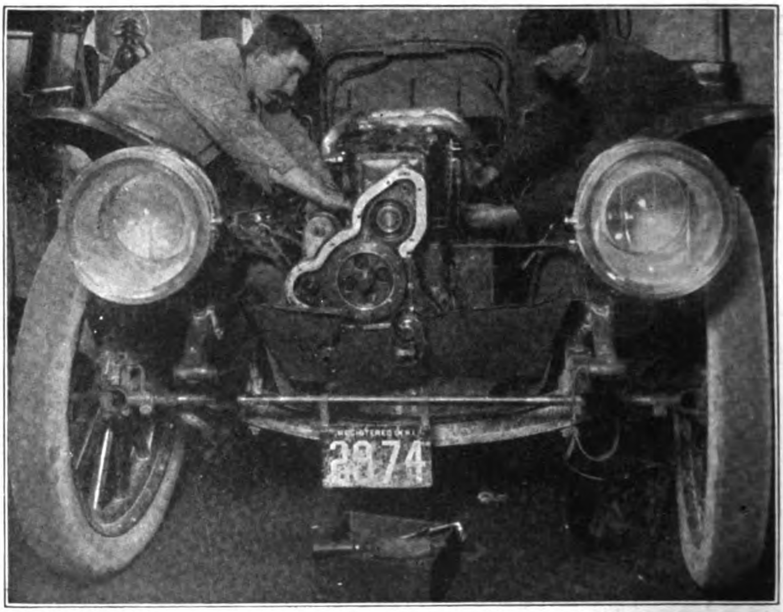

Fig. 39. Dismounting the Engine for Repair

When all accessories have been removed or loosened up, the holding bolts are taken out, and the clutch disconnected, leaving the motor free to be swung out by means of a small crane or hoist. In some cases, the work can be completed without disturbing the base of the motor, as in Fig. 40, which shows a big car partly

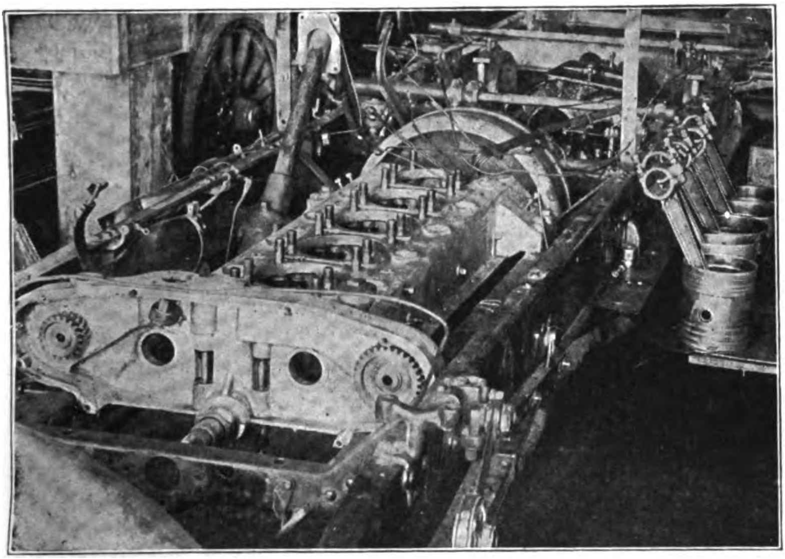

Fig. 40. Engine Dismounted Showing Cylinders Removed

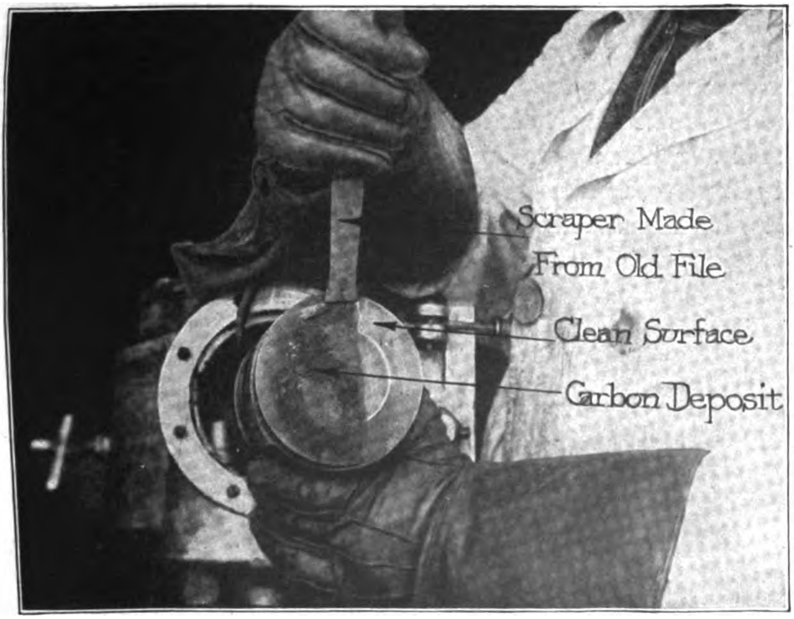

Fig. 41. Removing Carbon with File

disassembled for repairs, the radiator and cylinders being off at this stage. The trouble here was found within the cylinders, hence, as soon as they had been removed, the balance of the six-cylinder motor and its chassis could remain undisturbed.

Removal of Carbon. One of the first things the owners will meet is the removal of carbon. When the offending member has been brought out so it can be handled, the removal of the carbon can be accomplished in a few minutes. As shown in Fig. 41, the scraper is made from an old file, flattened out at the end, and ground down so as to present one sharp edge. Every owner should accumulate from five to a dozen shapes and sizes of scrapers for various work, including a flexible one with which to reach into corners, etc. A flat piston head like that shown can be scraped off with any knife or chisel, but a special tool is better. The carbon is brittle and comes off readily, after which the surface should be filed or rubbed over with emery and oil to make it smooth, in order to delay the formation of a second coat.

This is true of carbon in other places, but usually it is impossible to smooth the surface, in which case the process must stop when the part is scraped clean.

Removal and Replacement of Pistons. Speaking of pistons, there are several things that the beginner should learn about their removal and replacement. While it is not a difficult matter to pull a piston out of a cylinder, when both have been previously lubricated, and all proper precautions taken to loosen connecting parts, there are a few important things to remember.

The piston should be drawn out as nearly parallel to the axis of the cylinder as is possible, accompanied by a twisting motion not unlike taking out a screw, in case it sticks a little. If the piston sticks badly, pour in a little kerosene, which is thinner than cylinder oil, and work the piston in and out so as to distribute the kerosene between the two surfaces. When this member has been removed, the presence of carbon on the top will indicate the necessity of scraping the rings and the spaces below them.

To get at the spaces, the rings must be removed, and as they are of cast iron and very brittle, this is a delicate task. Two methods of accomplishing this are illustrated in Fig. 42. If the owner has a pair of ring-expanding pliers, the rings can easily be expanded enough to lift them over the edge as shown in (a). As very few owners possess this useful tool, however, a more common way is shown in (b). Secure a number of thin, flat steels about ½ inch wide and 1/16 inch thick, corset steels, flat springs, or hack saw blades may be used, although the latter require more care on account of the teeth along one edge. The length of these steels should be such as to reach from about an inch below the last ring to the top. Lift out one side of the ring with a small pointed tool and slip one of the steels between the ring and the piston; then move around about ⅓ of the way and insert another, taking care to hold the first in place; repeat the operation with a third steel. When these are in place the steels will hold the ring out from the piston enough so it may be slid over the "lands" between the grooves, and along the steels to the top.

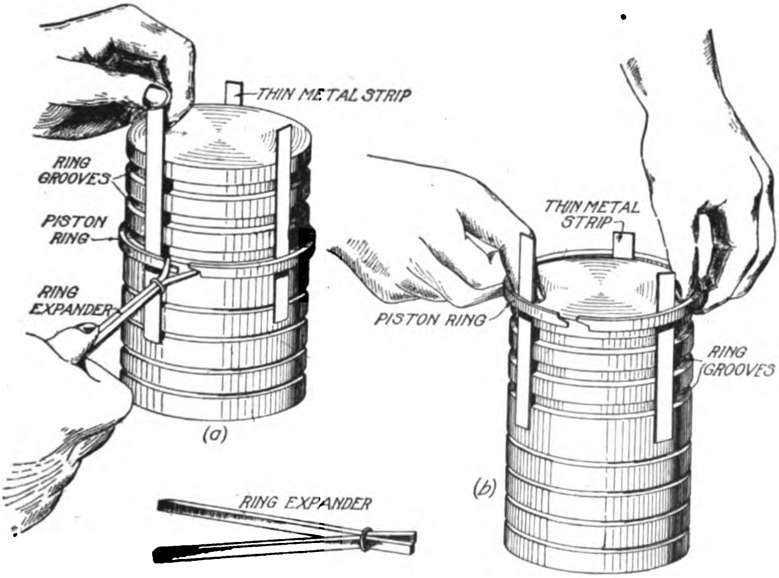

Fig. 42. Method of Removing Piston Rings

Always begin at the bottom, working up, when removing rings, and just the opposite, from the top down, when replacing them. After one is mastered, the removal of the others is a simple matter of repetition. The grooves can now be scraped free of the offending carbon, a process which is but an inversion of the previous method, after which it will be necessary to replace the rings.

Replacing the piston in the cylinder is a more difficult operation. There are two ways of doing this, viz, by a special form of ring closer, and by hand, using a string. The former is a shaped device which is clamped around the ring and squeezed together with pliers, using one hand, while with the other hand the ring is guided into the groove. The second and more usual method is illustrated in Fig. 43, and requires two men, unless the cylinder is of such a shape that it can be clamped in a vise. As the picture brings out, one man holds the cylinder while the other forces the piston carrying the rings into place. The piston is shoved in until the expanded top ring prevents further movement, when a heavy cord is placed around the spring, and the ends are crossed, thus closing up the ring and allowing the piston to slide in as far as the next ring. The operation is repeated successively for the other rings. This is a very simple method and requires only patience.

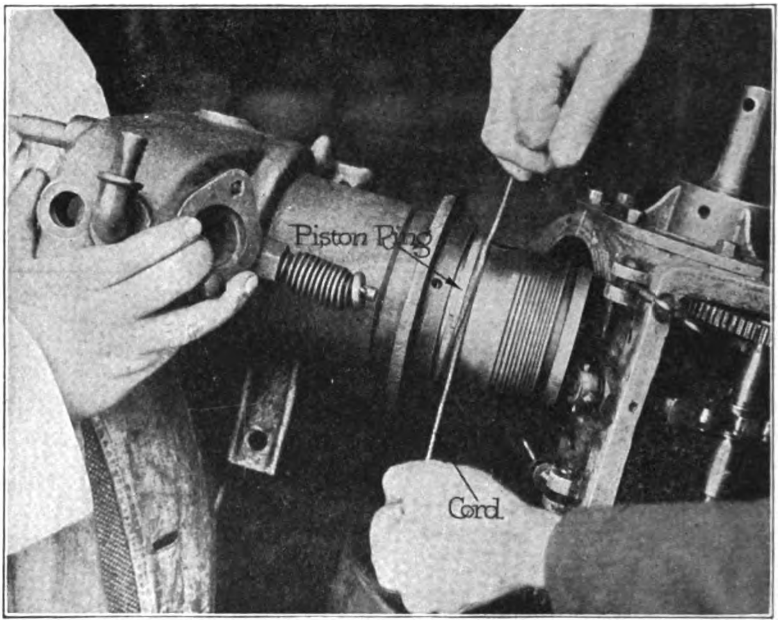

Fig. 43. Method of Re-Assembling Piston Mechanism

Bearings. Bearings of the two-piece or split type give the amateur repair man fully as much trouble as anything, in fact, the crank shaft bearings should not be tackled until considerable repair experience has been had. In general, wear on the bearings is due to one of two causes, either a soft metal which has caused vertical wear on the inside or outside of the lower half of the bushing, or a vibrating shaft which has worn an oval hole somewhere in the length of the shaft, as at the inner or outer end.

In the former case, the height of the worn half must be reduced, which is usually done by taking off from the upper face as much metal as is needed. When this has been done either by filing or by rubbing across emery cloth wet with oil, the two halves of the bushing will approach so close together that the hole will be smaller than the shaft. This will necessitate scraping out or reboring according to the amount which has been taken off. In the case of very small amounts, this wear can be taken up by removing shims, which are small filling strips of sheet brass which hold the halves of the bushing apart and thus make the central hole larger. The sizes of these shims vary from .003 to .008 inch, several of each being used. By selecting those which are to be removed, or taking out one size and replacing with another, any variation in diameter from .001 to .025 can be remedied. Of course this method changes the hole from a round to a slightly oval hole, but this may be remedied by a very small amount of scraping.

When the second form of wear is found, that is, when the bushing is worn oval by a wobbling shaft end, the only remedy is bringing the bearing halves together as before and reboring. It may be that this operation robs the bearing plates of so much metal that they will not fit the holes in the case; or possibly the wear may have communicated itself to the case, so that the hole there is out of true. If this be slight, refilling the cases with babbitt metal or building-up may be resorted to, but if the wear is considerable, a new set of bearings is the only remedy. In building up the bearing, strips of soft metal are placed in the worn spots, after cutting or filing them to fit as closely as possible, and the bearing driven down upon them as firmly as possible. In this way, it is often possible to build up a worn crank case to answer for many thousand more miles running.

Valves. Valves present another fertile source of trouble. These troubles may be of three varieties: Worn or pitted seats, worn or pitted valves, and bent or worn stems or stem guides. In the latter case additional air is admitted, allowing the mixture to become more dilute than the operator realizes until the engine begins to miss fire. If the stem be at fault, this may be turned down to a smaller size, perfectly round, and a new bushing with a hole of the new size fitted into place.

In case the trouble lies with the bushing, those of the one-piece type must be replaced if there is much wear; but if the wear is slight, a clever repair man can pein* the edges and considerable metal adjacent to them, so that a much smaller hole is formed, after which reboring to a tighter fit is in order.

When either the valve stem or seat has become worn or pitted, it must be reground. This is accomplished as follows: Secure a small amount of flour of emery, the finer the better, and mix this into a thin paste using cylinder oil, or graphite, or both. Loosen the valve, disconnect all attachments, remove the valve cap above, and free the valve in a vertical direction. Now lift it out, place upon the seat a daub of the emery paste and replace the valve. With a large screw-driver press the valve firmly in place, at the same time rotating it about one fourth of a turn to the right and then the same amount to the left.

While doing this, the other hand should be held below the valve stem with one finger just touching it. After moving back and forth about eight or ten times, lift the valve off of its seat with the finger, turn it through a quarter turn, and drop it back into place. Then repeat the grinding, until the whole circle has been covered several times. Then remove the valve and clean off both moving member and seat with gasoline. With a slight touch of Prussian blue, mark the seat on the valve, replace, and twirl around several times so as to distribute the color. Remove the valve without touching the seat portion on it or in the cylinder, and examine both. If the grinding process has been complete and accurate, the color will have been distributed in a continuous band of equal width all around the surface. If not continuous, or not of equal width all around, the task is but partially completed and must be continued until the full streak results. On the first attempt at this rather delicate piece of work, it is well to call in an expert repair man to examine and pass upon the job.

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*Force the metal nearer the center of the hole by means of a prick punch or by a pointed hammer.

Clutches. Clutches offer many chances for trouble, the wear of leather facings and the loss of power attendant upon this, slippery or dry leather or weak springs being the principal factors. Let us consider these in the reverse order. Weak springs may be cured usually by screwing up some adjusting nut or bolt provided for the purpose. Slippery leather may also be corrected by washing first with gasoline and then with water, finally roughing the surface with a coarse rasp and replacing only after the leather is thoroughly dry. Dry leather is fixed by soaking in water, or if possible in some oil or preparation which will soften it, like neatsfoot oil; the leather should be replaced while still moist, and copious lubrication will keep it soft.

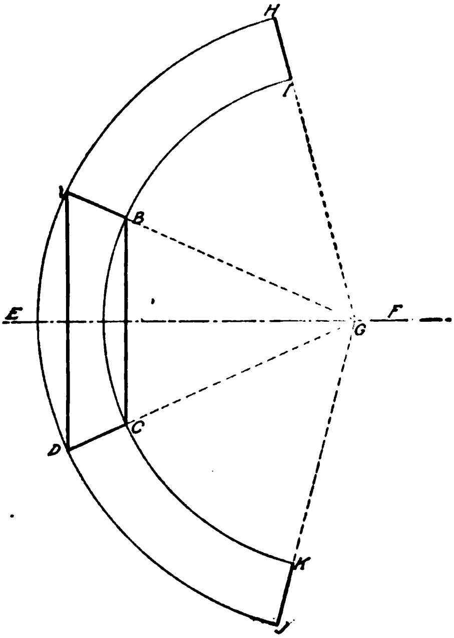


Fig. 44. Diagram Showing How to Cut Clutch Leathers

The greatest problem in replacing a worn, charred, or otherwise defective leather lies in getting the right layout for the form of the new leather the first time. It must be remembered that the surface is a portion of a cone and, therefore, its development is not easy. It is attacked in this manner: Prepare the cone by removing the old leather and all rivets, cleaning out the rivet holes and providing new rivets. Measure the cone, taking the diameters at both the large and small ends, and the width. Take a large sheet of paper, and lay off upon it a figure similar to *ABCD* in Fig. 44, drawn to exact scale and having for its dimensions the three measurements just obtained, viz, the large and small diameters and width of the cone. This figure represents the projection of the cone in a flat plane. Bisect the line *AD* and draw the center line *EF* at right angles to *AD*. Prolong the two tapered lines *AB* and *DC* until they meet the center line as at *G*.

This point *G* represents the apex of the cone if it were complete, and hence any circular arc drawn from this point as a center, and with the correct radius, will be a correct projection of the development of that portion of the conical surface. With *GA* and *GB* as radii, draw the two circular arcs *HADJ* and *IBCK*, also drawing the radial lines *HI* and *JK* to pass through *G*. The enclosed figure *HIBCKJDAH* may then be cut out and used as a pattern from which to cut out clutch leathers. If the distances *AH* and *DJ* be made approximately equal to or slightly more than *AD*, the pattern will a little more than encircle the cone clutch.

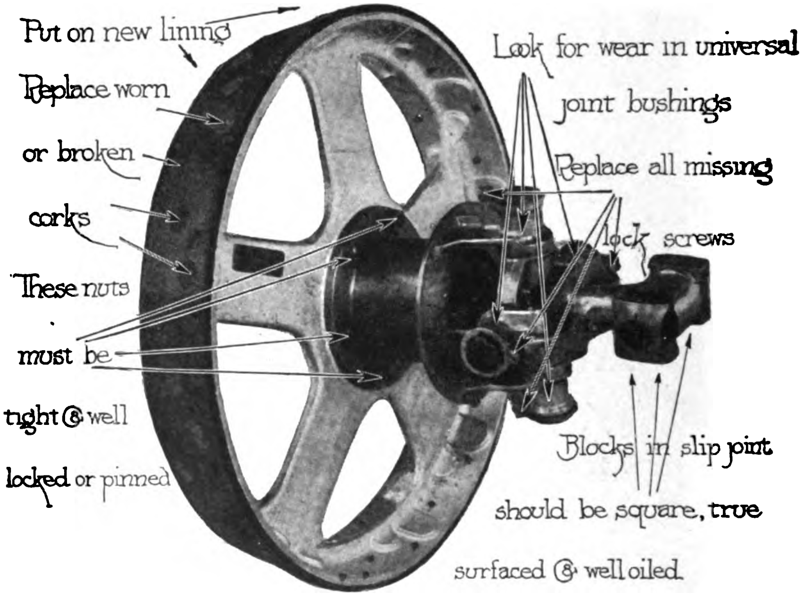

Put on new lining
Replace worn or broken corks
These nuts must be tight & well locked or pinned
Look for wear in universal joint bushings
Replace all missing lock screws
Blocks in slip joint should be square, true surfaced & well oiled.

Fig. 45. Clutch Troubles Illustrated

After the leather has been cut out, it should be prepared by soaking in water or oil, according as its surface is fairly soft or rather harsh. In either case, it must be well soaked, so as to stretch easily. In putting it on the cone, one end is cut to a diagonal, laid down on the cone, and riveted in place. Next, the leather is drawn down tightly past the next pair of rivet holes which are then driven into place. This is continued until the strip is secured. The leather is now wetted again, for, if allowed to dry off immediately, the shrinking action will break it out at most of the rivet holes and render it useless. By drying out gradually, a taut condition may be arrived at without this danger.

In Fig. 45, several other common clutch troubles and their remedies are suggested, the parts shown in the illustration, however, being in excellent condition, in fact new.

Transmission. Passing along to the transmission, Fig. 46 shows a plan of a gearbox in which the disk clutch is also housed, the various possibilities for trouble or suggestions for its avoidance being marked. In this type of clutch, the greatest possibilities lie in the burring of the disks or a lack of spring adjustment. If the former, the burrs can be filed off with a fine file, while the latter trouble is avoided by merely tightening the spring-adjusting springs, trying the effect of this and tightening again, until the correct and satisfactory position is obtained.

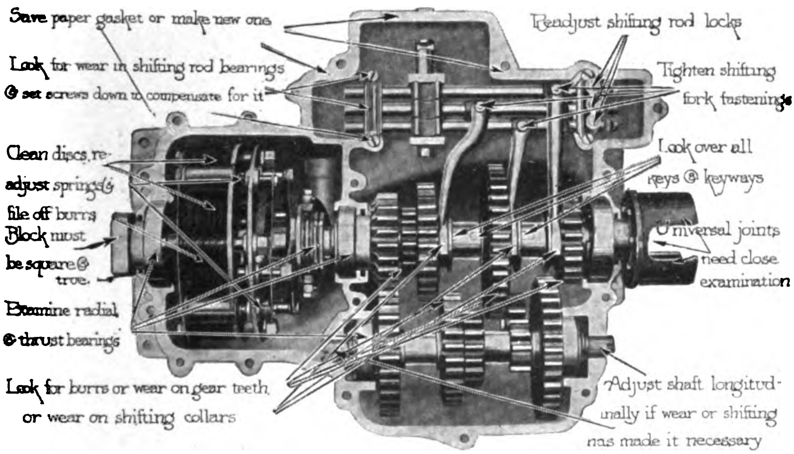


Fig. 46. Transmission Troubles Illustrated

In transmissions, the possibilities include the following: Burred teeth; gears worn where they slide along the shafts on keys or in keyways; looseness in the main bearings; and play in shifter rods or their locks. Where the gears clash, one against the other in shifting, unless the faces of each have been chamfered and rounded off nicely and are well hardened at these points, there is liable to be set up a cutting action which gradually wears a high burr in one or both. When the two are in mesh, the burrs are on opposite sides and contacting with the meshing gear. This will make a continuous noise. Its remedy is the removal of the gear, the filing off smooth of all raised portions, the filing or grinding out of all low spots cut into the teeth, and subsequent hardening to make repetition impossible.

If the gears have worn at the center hole where they slide on the shaft, either in the round hole or at the keyway, this must be fixed at once. In the former instance, the gear can be bushed, and the bushing bored out to fit the shaft, while in the latter, a slightly larger key may be fitted in the shaft and the keyway may be recut to accommodate this. Where the keys have been let into the shaft, they may have worn in one spot or at the ends. If the wear is all in the key, this can be replaced with another of the same size, but made slightly harder in the process.

If the main bearings are of the roller type, the wear may be taken up by readjusting the position of the roller on the cone, but if they are of ball or plain bushing form, replacement is almost the only remedy, unless it happens that in the case of a plain bush, this is split, so that something may be filed off of the two contacting sides, and the holes trued out to this new size. In that case, the advice previously given under the subject of plain engine bearings will be applicable.

Play in the shifting rods may be traced to one of two things: Looseness at the connection of two rods, or of a rod and a lever; or looseness in the bearings. The former inevitably requires a new and slightly larger pin, driven into the place occupied by the previous member. Loose bushings will mean new ones if the trouble is serious, for this form is almost always of the solid and, thus, non-adjustable type. In many cases where wear occurs on a solid plain bearing used on the end of a plain round shaft, if peining can not be resorted to, as suggested previously, the shaft may be turned down a very little bit, say $\frac{1}{16}$ inch, the bushing turned out an equal amount, and a thin sleeve bushing made of this thickness all around, and forced into the previous member. This saves reboring the case, which is an expensive and difficult job, while both the shaft and bushing jobs are simple ones.

If a serious defect develops in the case, this may be cleaned out and welded. This is not a job for the amateur, but the closing of a simple crack, no matter how long, would be an easy proposition for the owner of a welding outfit; moreover, it would be a very short, quick job. Autogenous welding should always be resorted to as soon as a crack or break is detected, for this may save the expense and delay of a whole new case, the former costing, say, 50 cents to $1 while the other easily may amount to $50.

Driving Shaft. From the gearbox to the rear axle the power, in the majority of cases, is transmitted by a long shaft. This may have either one or two universal joints in its length. The purpose of these is twofold: to permit the rise and fall of the rear axle relative to the rest of the car, and to allow similar side sway in which the whole rear construction participates. These joints are covered usually with leather casings which are packed with grease. These keep out the dirt and, consequently, lessen the wear, and also lubricate the moving parts of the joints. A secondary function of the casings is to render these joints noiseless. If a car is not equipped with them, it is advisable for the owner to purchase them.

The shape of these casings when opened out flat would be not unlike that of two bottles with their flat bottoms set together, that is, narrow at the top and bottom and wider at the middle. All along both edges are eyelets for the lacing. The enlarged center fits around the joint, while the small ends encircle the respective shafts. To apply the casing, one end is placed around the shaft on one side of the joint and the lace started; then the lacing proceeds, gradually drawing the ends together and around the joint. When this has been completed and before the last end is closed, the whole is shoved back along the first shaft a little way and the center portion half filled with a heavy grade of transmission grease. This done, the glove is pulled back into place and the work of lacing completed around the second shaft. Both ends should be laced as tightly as possible while the middle part should be loose.

Rear Axle. Rear axles do such hard work, and must stand up under such a large portion of the load carried in the machine, that they offer many chances for wear, adjustment, or replacement.

Brakes. First and foremost are the brakes, which now are usually placed side by side within the drum attached to the wheel, as shown in Fig. 47. This shows a semi-floating form of rear axle with the two sets of brakes and operating shaft and levers. A number of suggestions are placed upon this, among which will be noted this: "Renew worn brake lining and broken or loose rivets."

When a brake lining is worn, the proceeding is much the same as with a clutch leather previously described, with the exception that, whereas the latter must have a curved shape, the former can be perfectly straight and flat. This simplifies the cutting, but as most brake linings are made of special, heatproof, asbestos composition which is made in standard widths to fit all brakes, the cuttings of leather brake bands is not often necessary.

Truss Rods. Truss rods hold the wheels in their correct vertical relation to the road surface and to one another. If through wear or excessive loading, the axle sags so that the wheels tip in at the top, presenting a knock-kneed appearance, the truss rods must be tightened up so as to remedy this. Usually they are made with a turnbuckle set near one end, a locknut on each side preventing movement. The turnbuckle is threaded internally with a right-hand thread on one end and a left-hand on the other, so that a movement of the turnbuckle draws the two ends in toward one another, shortens the length of the rod, and thus pulls the lower parts of the wheels toward one another, correcting the tipping at the top.

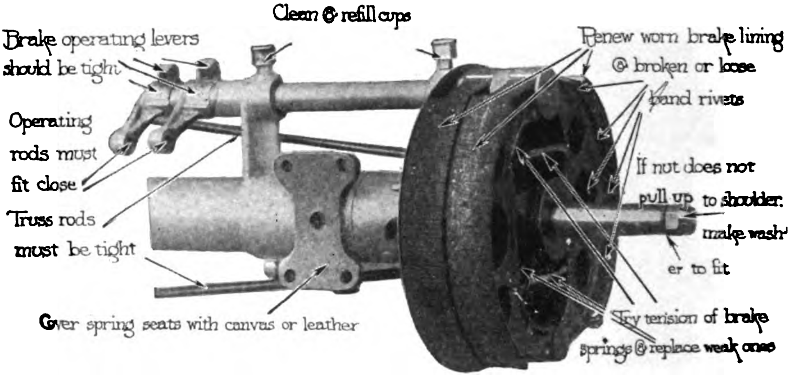

Clean & refill cups
Brake operating levers should be tight
Operating rods must fit close
Truss rods must be tight
Cover spring seats with canvas or leather
Renew worn brake lining & broken or loose band rivets
If nut does not pull up to shoulder, make washer to fit
Try tension of brake springs & replace weak ones

Fig. 47. Brake Troubles Illustrated

To adjust for this trouble, loosen both locknuts, remembering that one is right-handed and the other left. Then, with the wheels jacked clear of the ground, tighten the turnbuckle. A long square should be procured or made so that the wheel inclinations may be measured before and after. Placing the square on the ground or floor, which should be selected so as to be perfectly level, the turnbuckle should be moved until the tops appear to lean outward about one half inch—some makers advise more.

Springs. If either rear or front springs squeak, the car should be jacked up above them, and the leaves separated with a screwdriver or other flat tool. Grease or a mixture of grease and graphite can then be inserted between the ends of each pair of plates. This not only eliminates the noise, but also makes the springs work better and makes the car ride better.

Rear Construction. In disassembling the rear construction for purposes of adjustment or repair, the beginner should be very careful to mark all parts. Those parts which have been running together for many thousand miles act better and with less friction than would those which have never run together, despite the fact that the duplicate parts are supposed to be alike and interchangeable. It is therefore suggested that separate boxes be provided for the parts taken from the two ends or sides.

Method of Disassembling. The method of procedure for this is about as follows: Jack up the axle, replacing the jack with small horses or blocks of wood if possible. Then take off the hub caps, free the wheels, and take them off. Disconnect the brake operating rods and levers and remove them from the car, marking them carefully. Spread the brake shoes apart, loosen the springs at one side, and take out the springs, and then the brake shoes themselves. Remove the brake operating shaft with the cams; then disconnect the spring bolts and jack up the chassis, using the spring for a support. Disconnect all torsion or radius rods, and take off the grease boot around the universal joint in the driving shaft. Open this joint, and disconnect the shaft. Take this off, and if the spring bolts have been removed, the rear axle will be free. Pull this out from under the chassis, and if desired, further disassembling may be done more easily with the member clamped in a vise or laid on a bench.

Assembling. In assembling, almost the reverse of this process is followed, the parts going together in the opposite manner from that in which they were taken down.

Difficult Jobs Novice Should Avoid. The following jobs, sometimes lightly spoken of, are not considered advisable for the novice, or even a motorist with less than a year's experience, to tackle: Removing rear axle as just described; adjusting differential bevel gears; scraping main or connecting-rod bearings in the engine or principal bearings in a transmission; replacement of main, connecting-rod, or piston-pin bushings in engine, or principal bearings in the transmission; alterations in the clutch aside from new facing and spring tension adjustment; any internal work upon the magneto; any alteration in the timing; any change in the lubricating system; changes in valves aside from simple adjustment; alterations in the flywheel to increase or decrease its weight; any interference with the parts concerned with a correct running balance (connecting rods, crank shaft, flywheel, pistons, and rings); any alteration in the car operating system; changes in the braking, aside from spring tension; or other items of large importance.

Generally speaking, if the car operates properly, quietly, and efficiently, there is no real reason for the beginner with but a few months' experience attempting to improve upon the manufacturer's design and construction which are the results of years of study, the analysis of the experience of thousands of car owners of that and other makes, and in part a compromise between what the maker really would like to build and what the buying public demands and will have.

Tires. Before concluding these remarks on the general subject of small overhaul and repair work, it will be well to say something on the subject of tires. These are at the same time the most delicate, the most misunderstood, and the hardest working parts of a car. They are delicate because the materials comprising them are soft, pliable, and very easily damaged, as compared with the various selected metals entering into a car's makeup. They are misunderstood for various reasons, and in many different ways; composition, utility of and necessity for the various components, proper and improper methods of use, correct and incorrect inflation pressures, troubles and their remedies, and many other things, all come under this category.

Broadly speaking, all tires consist of two parts, the tube and the shoe or casing. The former is a plain round ring of circular cross section, made of pure rubber, containing an air valve, and is intended only to hold the air. The shoe or casing, on the other hand, provides the wearing surface, protects the air container within from all road and other injuries, and constitutes or incorporates the method of fastening itself to the wheel. In its construction are included the fabric—preferably cotton—some pure rubber, and much rubber composition, the whole baked into a complete unit by heat and in the presence of sulphur, which acts somewhat as a flux for rubber.

Considering a typical tire, there enters into its makeup, starting from the inside, six or seven strips of frictioned fabric—that is, with thin sheets of pure gum rubber rolled into intimate contact with each side of the cotton, making it really a rubber-coated material. Next, there is the so-called padding which is more or less pure rubber, has a maximum thickness at the center of the tread, and tapers off to nothing at the sides, but usually carrying down to the beading. Above this, there is placed a breaker strip, consisting of two or three layers of frictioned fabric impregnated in a rubber composition. This, too, is thickest at the center and tapers off to the sides, but ends at the edge of the tread. Finally, there is the surface covering, called by rubber men *the tread;* this contains very little pure rubber, being thickest at the center and extending with gradually decreased thickness almost down to the bead.

The last two of this series of layers constitute the real wearing surface of the tire, and when the surface is so worn that the breaker strip may be seen, it is time to have the tire retreaded. When the wear has gone through this, if the padding be fairly complete, retreading will still save the tire, but if wear has gone clear down through that so as to expose the fabric, the shoe must be run to a finish and then discarded.

An ordinary puncture simply penetrates the outer casing, and punctures the tube. When the latter has been patched, the whole tire is apparently as good as new. In reality, it is far from that for the patch on the tube will never be as strong as the original, while the hole through the shoe may or may not be the cause of a subsesequent blow-out or other severe trouble. If the rubber composition is at all torn, this should be taken to a repair man for a small insert of patching rubber, and vulcanization. This makes the shoe practically as good as new, for the vulcanizing operation incorporates the small patch into the tire as firmly as any other part of it.

If not vulcanized, a small pebble may lodge in this little hole, and through the pressure of the car upon it and road shocks and blows, may be driven gradually inward, opening up the hole as it goes, until other and larger stones are picked up, driven in, and the work of destruction continued. This goes on, if the owner does not notice and fix it, until the material above the air tube, pumped up to perhaps 75 or 80 pounds pressure per square inch, becomes too thin and weak to support it longer, when a small explosion takes place, the air bursting through the envelope. This is technically known as a blow-out, and if severe or far reaching, may put the valuable casing beyond the reach of repairs.

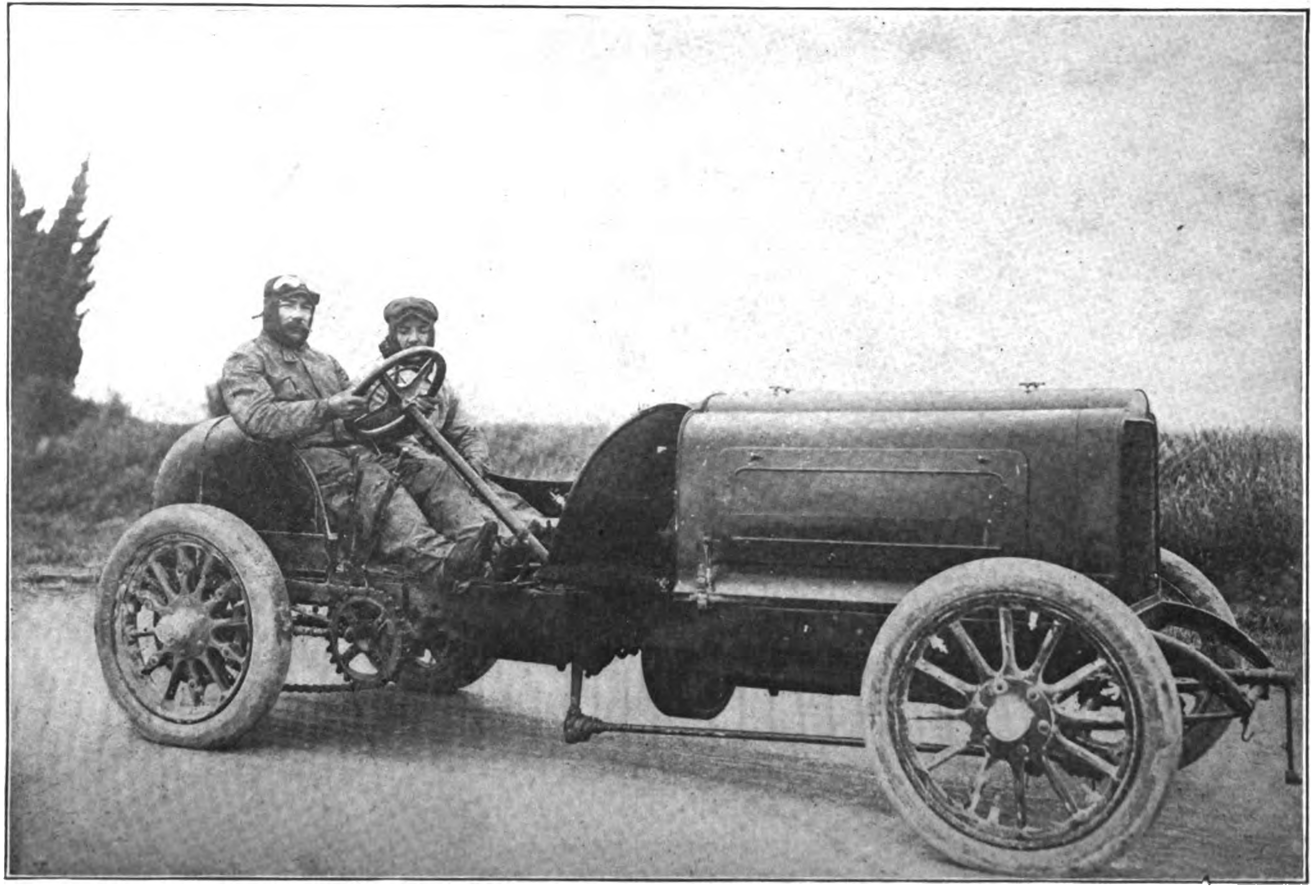
Not all blow-outs are caused in this way, many occurring on the side of the tire where a fault develops, which is enlarged by a blow or cut, until the material can stand the internal pressure no longer. When the car is run continuously in car tracks, or in the deep ruts of a country road, the thin sides of the tire chafe off very rapidly, more so than the tread under similar circumstances, for the rubber on the side is purer and, being softer, cuts more easily.

Whenever the surface of a tire, comparatively new and thus worth looking after, is injured and a portion of the material accidentally removed, it is well to repair this and vulcanize it one's self, or else take it to the tire repair man. These few remarks, all including some mention of the ever useful vulcanizer and its utility, but lead up to the statement that every motorist should own one of the accessories and utilize it upon every possible occasion.

While neither this treatment nor anything else will make an old tire new, it will help greatly in keeping a new tire new and in the best of condition, it will keep the tire repair bills down to a minimum, and it will decrease greatly the tire cost per mile, and in these and other ways contribute much to the pleasure of motoring.

Washing tires often is a good practice, for water does them no harm, while all road and car oils and greases will be cleaned off, nearly all of these being injurious. Frequent washing will also serve to call the owner's attention to minor defects while they are still small enough to be easily repaired and are thus prevented from spreading. When not in use, tires should be wrapped, so as to be covered from light, and put away in a dry room in which the temperature is fairly constant the year around. They will not stand much sunlight, nor many alterations of temperature. Cold hardens the tires and causes rubber to crack. Heat has a somewhat similar effect and also draws out its life and spring.

In general, of all things to be cared for and repaired promptly, no one thing is of more importance than the tires. If this rule be kept in mind, better satisfaction in the use of the car will result. So, too, with other repair work, if tools and appliances are made available, and repairs made as soon as needed, the car will be better understood and give more satisfaction than if the opposite course be pursued. A few short months' use of a car will do more to emphasize this than any amount of talk. Keep your car in good condition and you will reap the benefits of the little work you do upon it.



MORS CAR
With Collomb (A World's Record Holder) Driving.

AUTOMOBILE DRIVING

First get your car, then learn to use it. This homely phrase based on another one equally homely and of daily use, sums up in a few words the matter of learning to drive a car. After the car has been duly purchased, the glib salesman will show one in about four minutes how to drive. Yet after all this assistance, it will take almost any man of fair intelligence a whole week or more to learn to run the car alone and with confidence, while he will continue to learn additional points as long as he continues to drive. Although the gasoline engine, in combination with the other mechanical parts of the ordinary touring car, is not so very complex when tackled in a common-sense manner, there are so many things which enter into the whole makeup and which may vary, either singly or in combination with others, that the combinations are practically infinite.

STOPPING THE CAR

Of premier importance is starting, and the proper way to go about it. But even before this is done, the beginner should learn to *stop* the car, for accidents often happen from inability to stop; never from inability to start. So, the first thing on the novice's program should be the matter of stopping.

Closing the Throttle. Without a doubt, the surest way to stop the car, one that is always effective, and by all odds, the first one for a beginner to learn is that of shutting off the *throttle.* This he must learn at once and before he learns anything else; it should be so thoroughly grounded and fixed in his mind that no matter what sort of a discomfiting situation he finds himself in, he will always think to shut off the throttle. This is effective, in that with the throttle closed, no gas can reach the engine, which, therefore, cannot run. If no gas be supplied and the engine cannot run, its own internal resistance, to be explained more in detail later, will stop the car very quickly, though not immediately. Other methods will stop the car more quickly, but the novice might release them accidentally before the source of trouble was removed, making the situation as bad as, if not worse than, before. With the throttle closed, the engine stops and with it, of course, the car.

Fig. 1 shows how this is accomplished. Nearly every car has the spark control and the throttle placed upon the steering wheel, so as to be convenient. Practice varies whether the spark is placed above or below the throttle, but in any case, it is an easy matter to ascertain. This is done by lifting the *hood,* or *bonnet* as it is variously called, so as to expose the mechanism. Then any movement of a lever on the hand wheel moves either a part of the ignition apparatus or some portion of the carbureter. If the latter, the lever moved is then the throttle lever.

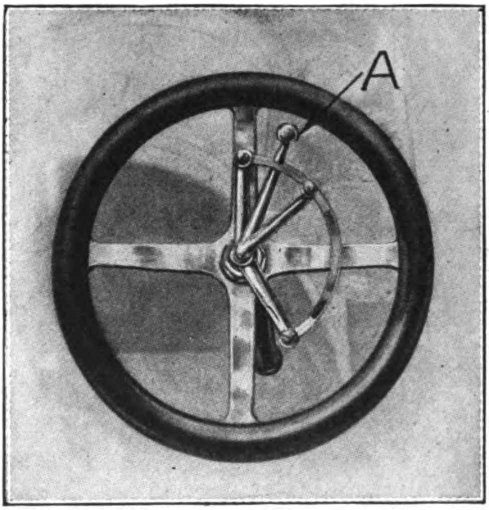


Fig. 1. Typical Steering Wheel.

It is not necessary to remember which movement of the throttle turns the mixture on or off, since, if the car is running, it must of a necessity be turned on; and to stop, it is only necessary to move it as far as possible in the opposite direction. In Fig. 1, the longer and more easily operated lever, marked *A*, is the throttle lever, and is shown in the "off" position. In the "on," or open position, this is at the side, where it is more convenient to the hands, which should always grasp the wheel at two points directly across the rim of the wheel from one another, *i. e*, 180 degrees apart. The ordinary application of levers is such that in this position, the location of the spark and throttle levers will bring them down close to the right hand; in which location, they may be operated without removing the hand from the wheel, a slight movement of the thumb or one finger being sufficient. For the "off" position, on the contrary, it is necessary to remove the hand from the wheel and reach for the levers, either to put them both in the "on" position or both on the "off" location.

When the danger or source of trouble is fully removed, it is the work of a second to get out and start the engine again. This method of stopping the car by shutting off the engine, the beginner must learn at once and remember for all time, although later on, with more skill in handling the car, and increased presence of mind, the other and superior methods will doubtless be used in preference. This one has the merit, for the beginner, of removing for a considerable length of time all possibility of future danger, and only recurring of the novice driver's own volition. That is, there can only be additional danger when the engine is deliberately started again.

Emergency Brakes. Other ways of stopping the car are numerous, as stated before, but to mention them in order of merit, the best is a combination of the method just mentioned with the application of the *emergency brakes.* The latter are placed on the car, as their name would indicate, for the express purpose of stopping the car in an emergency. Usually they consist of a pair of very large and powerful brakes fixed directly to the rear wheels and operated by the outer of the two hand levers. These hand levers may act forward or backward, *i. e.*, they may be applied by a pull or a push. The method to be used will depend upon the specific car in question, since the makers differ as to this and the system of operation has never been wholly standardized.

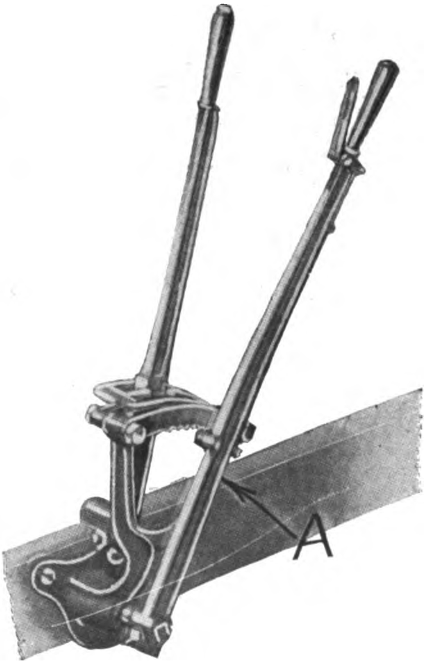


Fig. 2. Side Levers of Pope-Hartford Car.

Two figures are given to show this. Fig. 2 is that of a popular car on which the lever *pulls back* to apply the emergency brakes.

The right-hand lever, marked *A*, is for the brakes. This is retained in place by a ratchet which is discernible on the under side of the quadrant bars. In Fig. 3 is to be seen the controlling levers of another equally popular four-cylinder touring car, on which the emergency brake lever, marked *B*, *pushes forward* to apply the brakes.

Service Brakes. All modern cars are equipped with a secondary set of brakes, which are known as the *service brakes*, and are applied by means of a foot pedal. While this has not been standardized any more than the action or placing of the emergency brake levers, it happens that the majority of car builders utilize the right-foot pedal for this purpose. This operates a second set of brakes placed upon the rear wheels of a shaft-driven car, according to the latest practice, or upon the countershafts of a chain-driven car. It is sometimes a single, wide-faced brake placed upon the main shaft just back of the transmission as shown at *C*, Fig. 4. In any case, pressing the pedal *D*, Fig. 3 and Fig. 4, forward and down applies the secondary set of brakes. These being applied by means of a foot pedal while the emergency brakes are operated by means of a hand lever, makes it possible to apply both at once, with superior braking results. In the use of a *pull-back* emergency lever, it is possible to apply the foot brake first, and with the leverage upon this as a brace, apply the emergency brakes more forcibly.

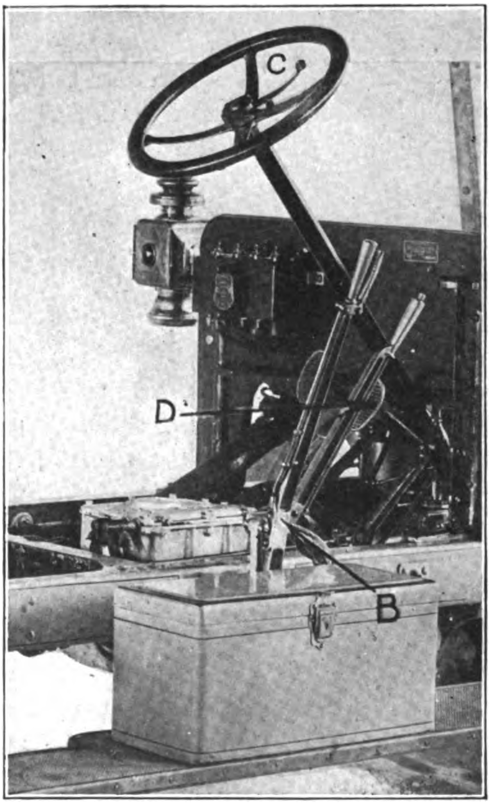


Fig. 3. Control Group of Mora Car.

It must be remembered in the use of both of these, that the operator is simply using his strength and the increased leverage which the arrangement gives him, against the force of the engine, and that other conditions being the same, when the foot pedal and hand lever are removed or released, the engine will go on propelling the car just as fast as before the brakes were applied.

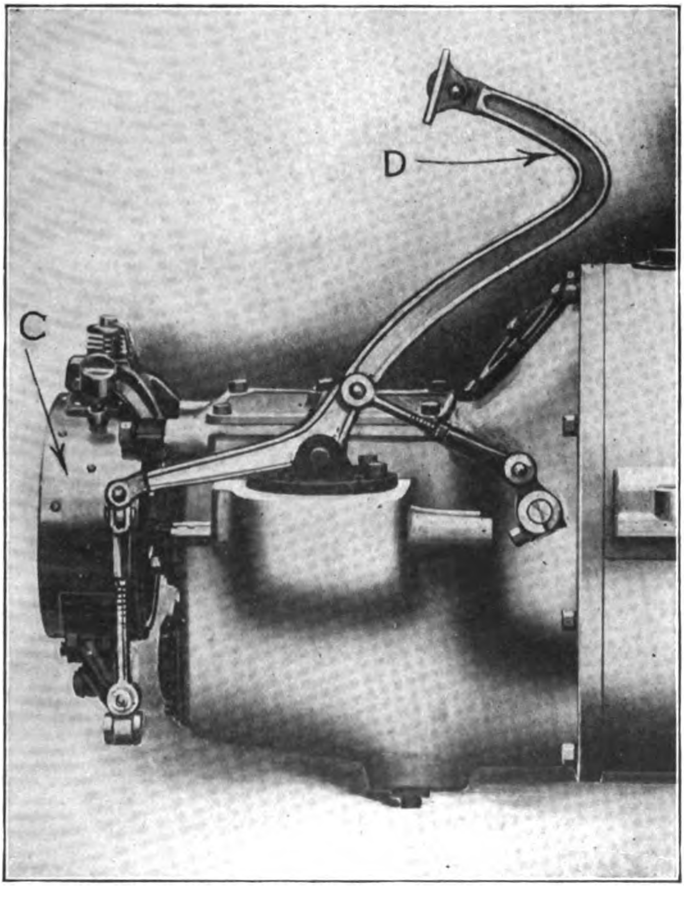


Fig. 4. Service Brake and Operating Pedal on the Chalmers.

Using the Engine as a Brake. A fourth method, and one which takes care of the case just mentioned, is that of throwing off the spark. This is brought about by means of the spark advance lever on the hand wheel previously spoken of, and shown at *C* in Fig. 3.

Throwing off the spark prevents the ignition of the charge just drawn into the cylinder, or any succeeding charges, until the spark is again thrown on. This causes the engine to draw in gas, compress it, and eject it without receiving a power impulse. All this takes power; since none is supplied, the forward energy of the moving car is consumed in turning the engine over; this rapidly subtracts from the momentum of the car, and in that way soon brings it to rest. In the language of the automobile driver, this is the act of *using the engine as a brake.* Despite its effectiveness, the practice is to be deprecated because it is at the same time wasteful of fuel and is said to be hard on the engine which, after all, is the vital, beating heart of any car, and should have corresponding care.

Changing Gears. The last method of snubbing the forward progress of the car consists of nothing more nor less than slowing down by shifting to the *low gear,* in which, as will be explained later on, many revolutions of the engine are necessary to make one rotation of the rear wheels. In conjunction with this, a retarded throttle will lower the movement of the car to a veritable crawl. This is usually very handy to know and to utilize in the crowded streets of large cities, particularly in the downtown districts during teaming hours.

Having then mastered the numerous ways of stopping and slowing the progress of the car, including the one to be most firmly impressed upon the mind—that of shutting off the gas supply by retarding the throttle lever to the limit—the amateur driver can begin to consider something else, which would naturally be the process of starting and the routine of inspection which precedes it.

STARTING THE CAR

Method. The best way to go about this is to have a simple routine, which is always followed. In order to always do the same thing and in the same order, it is well to have a list of things to be done, which should be learned and always followed. In a short time the driver will do these things unconsciously each time before starting out, and then the simple system will have served its purpose.

Now as a suggestion, one might say to oneself, what are my wants? and, after having attended to them, have I got everything? The key words to these two simple questions are the words WANTS and GOT. Taking these as the keywords, it is possible to lay down all of the things that should be done before starting, so that every letter of these two words represents one thing, as follows:

W ater
A cetylene (or lamps)
N uts and bolts
T ires
S park retarded

G asoline
O il
T rying out

Water. From the above, water stands for the question, is the water cooling system completely filled, or does it need any more water?

Acetylene. Then comes the question of proper lights—is there sufficient fuel to light the car on its way, whether it be acetylene compressed into tanks, generated from carbide, or just plain oil; or in the modern electric method is the lighting system complete.

If a gas tank is used instead of a generator, the autoist should see that the pressure gauge indicates that there is sufficient gas in the tank for the trip, and, if not, the tank should be replaced by a charged one.

In connection with filling the lamps it would be well to form the habit of wiping the tail-lamp glasses and the license-plate with a cloth, as these are usually neglected and become obscured by dirt, and may subject the autoist to arrest for not having a rear light or a legible license-plate.

Nuts and Bolts. Next, it is wise to glance over the more important bolts and nuts to see if they are tight, or at least appear tight. At first it is well to go over them with a wrench, but later on this is unnecessary.

Tires. Now the tires represent a very important part of the car, one that is very expensive to buy and maintain, so that it is a good idea to get into the habit of glancing at all four tires before setting out on any kind of a journey. In particular, the inflation should be examined. Tire manufacturers say that 35 per cent of tire troubles are due to under-inflation. In this connection, the table of tire pressures, Table I, will be very useful. It may be used in connection with any kind of a tire-pressure gauge. There are a number of these gauges on the market, and the beginner should obtain one very early in his driving career, learning to use and rely on it.

TABLE I

Proper Pressures in Tires

Size of Tire	Pressure Recommended		Weight per Wheel	
	Front	Rear	Front	Rear
28 by 2½	40	45	225	275
30 by 2½	45	50	225	275
28 by 3	48	52	350	425
30 by 3	50	55	375	450
32 by 3	52	58	375	450
34 by 3	52	60	400	500
28 by 3½	55	63	400	500
30 by 3½	58	65	450	550
32 by 3½	60	65	500	625
34 by 3½	63	65	550	675
36 by 3½	63	68	600	750
30 by 4	63	68	550	650
32 by 4	65	70	650	800
34 by 4	68	70	700	875
36 by 4	68	72	750	900
32 by 4½	68	72	700	800
34 by 4½	70	75	900	1125
36 by 4½	72	78	1000	1250
34 by 5	75	80	1000	1300
36 by 5	80	90	1150	1375
38 by 5	85	100	1250	1500
36 by 5½	90	105	1400	1600
38 by 5½	95	110	1500	1700

Spark. To save his own body, or to be more specific, his arms and shoulders, the driver must retard the spark every time before attempting to start the engine, else a back kick will result and injury will surely follow. This is an important point and one that, like shutting off the gas in an emergency, should be memorized early. The importance of this may be judged from the statement, borne out by the reports of insurance companies, that 37% of all automobile accidents to either driver or passenger, are cranking accidents.

Gasoline. Surely, the engine has not yet been invented which will run without fuel, so it is of primary importance to have not only some fuel, but enough to complete the proposed journey. This then stands for the question, "Is the gasoline tank filled?"

Oil. Lubrication is of equal if not superior importance, for even if everything is right and ready to run, with plenty of fuel, to run it without lubrication is to run it for the last time, *i. e.*, a lack of lubricant (oil, grease, graphite) will ruin the finest machinery.

After having started the motor, the autoist should listen for any unusual sounds while it is running, and closely watch the sight-feeds on the lubricator, adjusting them if necessary.

Trying Out the Car. After starting the engine the autoist should take his seat, and, withdrawing the clutch, place the shifter lever in the position for first speed, release the brakes, and start the car by engaging the clutch gradually.

While the car is moving the brakes should be operated, first the hand brake and then the foot brake, and if any adjustments are needed they should be made at once. A trial of the brakes with the car running is more valuable than a number of trials with the car at rest.

If the gear-shifter lever does not work properly, or the clutch slips, the fact will be indicated, and adjustments can be made on the spot, saving the autoist trouble and humiliation on the road.

Things to Remember About Starting. Next to the points covered above, the most important thing for the beginner to learn is the proper method of starting an engine, and of holding the starting crank so as to render the process a safe one. These are very hard things to impress upon the novice, who thinks that starting consists of turning the crank—a very simple operation—until the engine responds and starts. This is very far from the real situation.

Method of Cranking. The proper and safe method of starting should be learned for there are methods in daily use which are not safe. Take, for instance, the ordinary way of cranking the motor. Most motors turn clockwise, that is, from left to right. Then, in starting, the ordinary driver, who has just "picked up" driving, grabs the crank with the *right hand* and pulls on it until the top is reached, then pushes it over the center, and the motor either does or does not start. In the latter case, he continues to pull it around. This method, whether right or wrong, may possibly work on a small engine, but wait until this plan is tried upon a large motor.

The driver, to crank in this fashion, must stand at the left and between the center of the car and the wheel or fender. At the top of the stroke, which is also the top of the circle of revolution of the crank, he is in a very awkward position. Worst of all, his arm is extended stiff, and a back kick will operate directly against it, as shown at the left in Fig. 5, and shown also in Fig. 6. In this manner the arm is liable to be broken, or at least badly wrenched. In addition, the awkward position is such that the weight must be concentrated upon the right foot in order to balance. The least tendency toward back-firing is liable to destroy this balance, so that the driver may fall over. The writer has seen men start a car in this fashion, and, finding the engine turn over more readily than they had expected and provided for, the very effort of starting was sufficient to upset their balance and cause them to fall over.

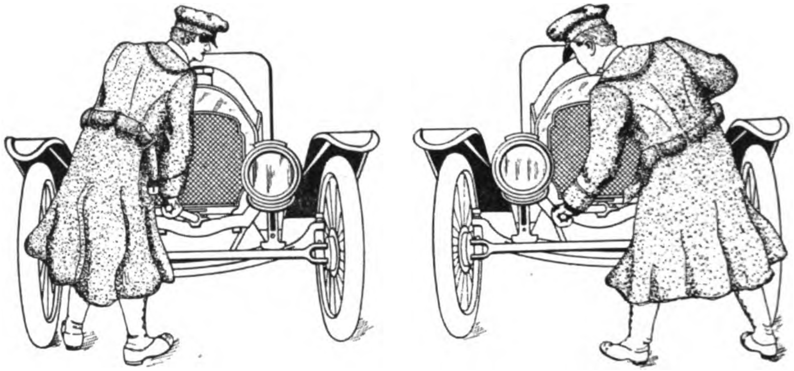


Fig. 5. Wrong and Right Method of Starting.

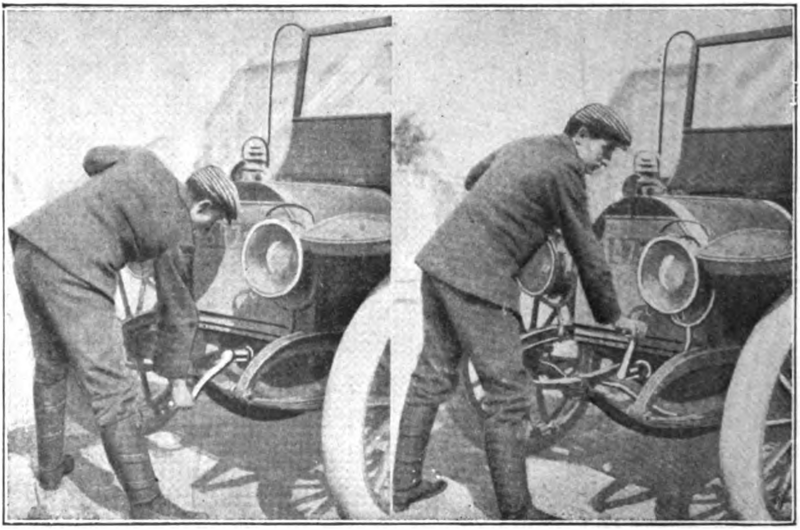


Fig. 6. Pulling (right way) Contrasted with Pushing It (wrong way).

With *left-hand* starting, however, these three objections are obviated. As the turn of the crank is away from the center of the car, its movement may be counted upon to give the driver more room in which to stand. Instead of the last and hardest part of the cranking being in the nature of a push with the arms stiffened, it is more of a pull with the elbow flexed, and therefore free, as shown at the right in Fig. 5. If the engine back-fires it is easier to let go of the spinning crank, because it is exerting a pull on the hand, not a push as before. Then, too, the substitution of a well-balanced position for an awkward one helps to make the action of freeing the crank so as to let it turn freely, much easier. The advantages of left-hand starting, then, may be summed up as follows: less danger to the operator's arm, easier balance of the body, and less work.

How to Hold the Starting Crank. In the apparently simple operation of cranking an automobile engine there are many little points for the novice to consider. Among these the most important are those which make for increased safety. Thus the seemingly elementary action of grasping the crank handle is susceptible of two methods—one, right and safe; the other, not safe, and therefore, not right.

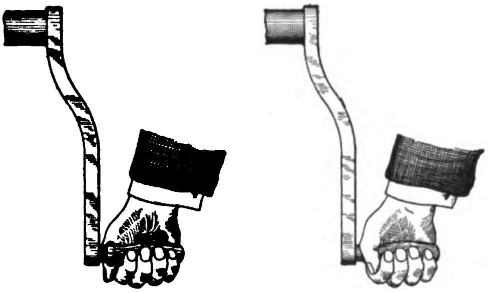


Fig. 7. Right and Wrong Crank Grip.

Ordinarily the driver will grasp the handle with a firm grip about as he would grasp a baseball bat; that is, with the fingers wrapped around it in one direction and the thumb around it in the other, as shown at the right in Fig. 7. Whatever method of cranking is employed, this grip is wrong, for if the motor back-fires the position of the thumb prevents letting go, at least quickly enough to be of any service.

The proper way, as shown at the left in Fig. 7, is to take hold with the fingers around the handle, but loosely, never tightly. Then the thumb should not be used at all, but should be folded back alongside of the first finger and out of the way. The whole work is done by the fingers, and if anything happens the backward action of the crank simply opens the closed fingers and no harm is done. This holds true particularly when taken in conjunction with left-hand starting. In that case, the latter and dangerous part of the starting action is a pull toward the operator. The arm in which the greatest strength can be exerted, is in tension, So, if the engine back-fires, a person just stands still and holds the arm taut, while the backward action of the engine opens the fingers.

There have been a number of devices brought out to eliminate cranking, and with it, the danger, but very few of these have been commercially successful. The most successful modern mechanisms are all based upon a source of compressed gas—either exhaust or compressed gas on the one hand, or compressed air on the other. Then, there are a few mechanical devices, such as the strap starter, the various spring arrangements, and others, nearly all of which present much complication. A new device, which does not possess this fault and which is simple to attach as well, is the S-W *auto-crank.* This, contrary to the usual practice, is placed on the dashboard, and looks not unlike a coil box, except for the projecting shaft end, Fig. 8, Fig. 9, and Fig. 10. It consists of reduction gearing, thus giving the operator the advantage of mechanical reduction, which results in increased

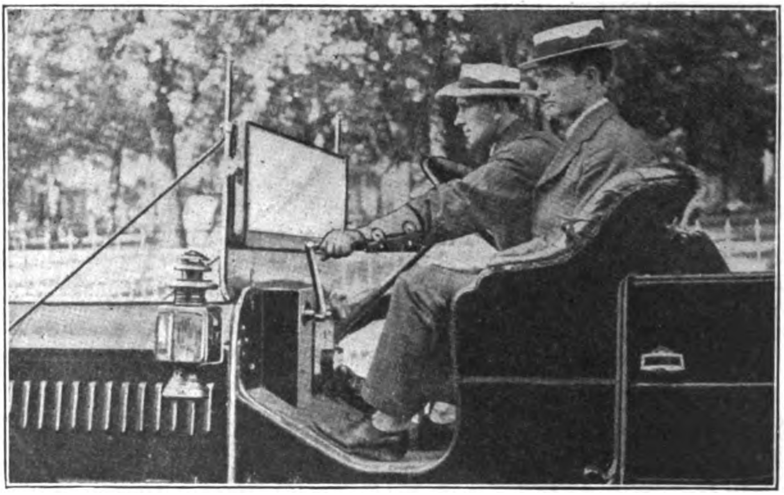


Fig. 8. Cranking from the Seat with an S-W Auto Crank.

safety. Then, too, the device incorporates an automatic release for use in the case of a back-fire, as well as for the prevention of backlash.

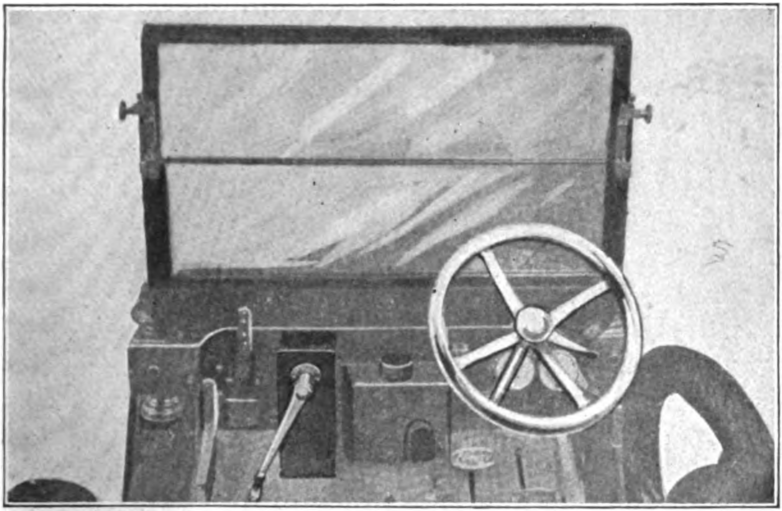


Fig. 9. View of Dashboard with S-W Crank in Position.

The automatic release comes into play when the engine is running normally, and under such conditions the crank does not rotate.

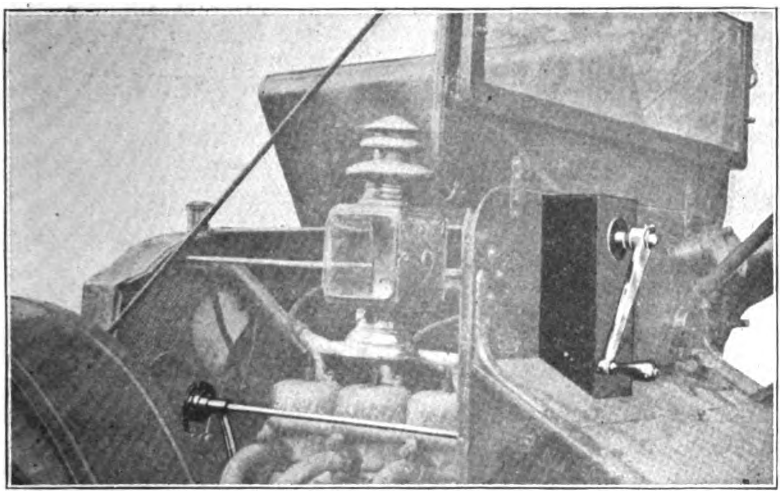


Fig. 10. Side View of Auto Crank Connections.

CONTROL

That one should master early the methods of control is easier to say than to do as is shown plainly in the two charts, Fig. 11 and Fig. 12. These depict the action of changing gears on a number of different American cars, and show at a glance the wide divergence in practice which the new driver must go up against. The upper figure is meant to represent the quadrants of cars having four-speed gears, and the lower figure, the quadrants of those cars fitted with three-speed gear boxes. By four speed and three speed, is meant respectively four forward speeds and three forward speeds; the reverse speeds, being taken for granted, are not counted in mentioning the number of speeds which the gear box affords. Thus, to call attention to a few of the types selected at random, *A*, Fig. 11—the quadrant on the Lozier Model G—has the reverse on the outside and forward, while the high speed is also forward but inside. The low speed is outside and backward, while a forward movement of the lever in the same line gives second speed. To attain third speed, when in high, is simply a matter of pulling the lever straight back. In *C*, Fig. 11, are shown the various lever positions on the Studebaker car. Again the reverse is to be found on the outside and forward but there the resemblance ceases, for the high speed is outside and forward, as compared with inside and forward on the Lozier. Low speed is inside and forward as contrasted with the Lozier's outside and back. Second speed is found inside and at the back as against outside and forward on the Lozier, and similarly with third, which is outside and back, instead of inside and back. This would lead to much trouble at first, as for instance, when a person who was used to a Lozier and was driving a Studebaker for the first time, was caught in an emergency, and dropped to reverse, desired to go into low, he would involuntarily go through the Lozier movement to which he was accustomed, namely, outside and back. This done upon the Studebaker results in third speed, which is very high as compared with the expected low. Sequel, an accident. Of course, this could only happen during the first few weeks of use of a new car, as after that time in any situation, it would be a matter of doing the shifting according to the quadrant of the new car. But to prevent just such a happening, the control should be mastered thoroughly, and learned so that one can

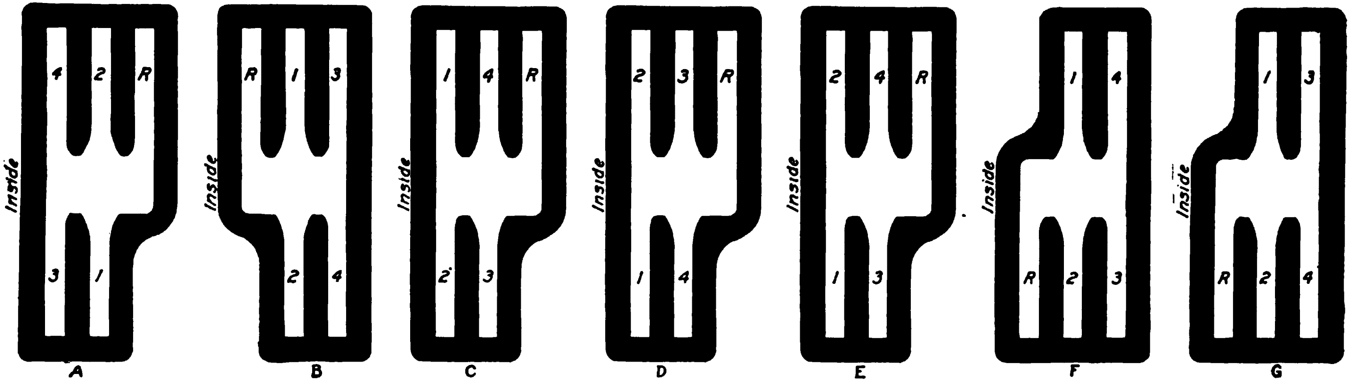


Fig. 11. Variation in Typical Four-Speed Selectors on American Cars.

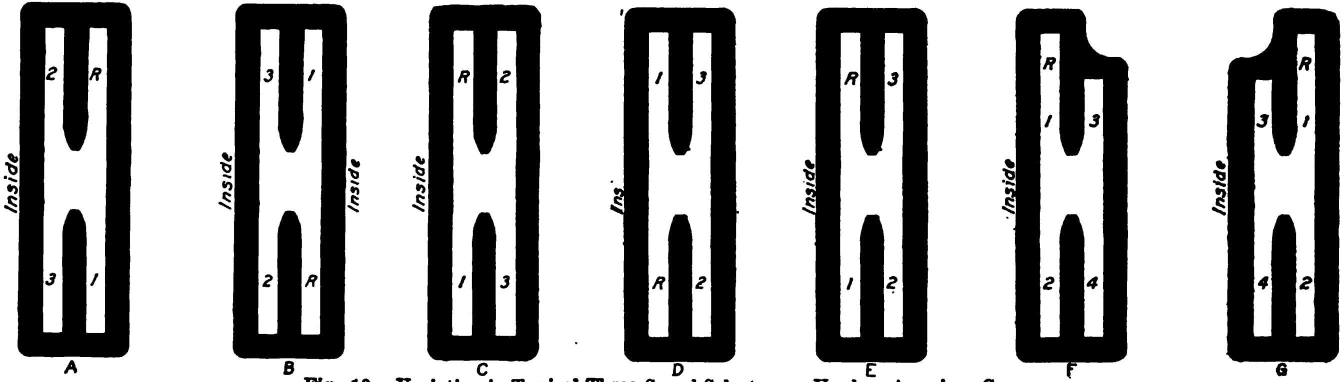


Fig. 12. Variation in Typical Three-Speed Selectors as Used on American Cars.

repeat upon request, the various speeds and the corresponding positions. Changing gears is at once a peculiar and a complicated action, for the clutch must be thrown out for an instant, during which the levers are shifted, after which the clutch is gently let in again.

Proper Procedure in Gear Changing. One thing that should be mastered early in the process of learning to change gears, is that the motor and the car should be moving at corresponding rates of speed. That is, when it is desired to change down from a high to a lower speed, if the car be allowed to slow down a little before changing, better results will be had. This may be effected by throwing the clutch out and holding it out for a short time, when the car will slow down a little. If this is done, the engine being free for a time, will begin to race and so the changing process must be accompanied by a closing of the throttle to reduce the engine speed. Similarly with changing from a low speed up to a higher one, the car should be moving rapidly, and the change should be made as quickly as is possible, so that the car does not lose any of its momentum. With the planetary type of gear, the matter of changing speeds is very simple, consisting of but a push on one or the other of two pedals, this action supplanting both clutch and change gear lever action on a sliding gear transmission. With this form, drivers usually guess at the proper period at which to make the change, any mistake in estimating the rates of the car and motor being of little consequence, as the bands will slip instead of transmitting the shock to the gear. A similar action occurs in the case of individual clutch or friction gears, but with the sliding type severe strains and shocks have to be taken up by the clutch and are usually transmitted in part to the gear if the clutch is not slipped. What applies to the sliding type in general, applies to the other types as well.

Changing from a Lower to a Higher Gear. In changing from a lower to a higher gear it will be necessary to speed up the motor by means of the throttle or accelerator in order to store enough energy in the flywheel to furnish the work needed to accelerate the car to its new speed. As the speed of the car increases the higher gear should be engaged, the autoist not being in too great a hurry to make the change; however, the movement of the change gear lever should be made quickly in order that the car does not lose way. When changing from a higher to a lower gear the change should be made so quickly that the car has no time to slow down. When climbing a steep hill it should be ascended as far as possible on the high gear by proper use of the throttle and spark, and the change down to the lower gear made as soon as the motor begins to labor or is in danger of stopping. The presence of an unusual number of passengers in the car will affect its ability to negotiate grades which ordinarily are taken on the high gear, and the autoist should remember this and not attempt to force the car to travel on that gear with the increased load, but resort to a lower gear.

Changing with Selective Gearing. Of the two chief varieties of sliding gear the selective is in more common use. The most familiar form employs a sort of grid with communication between the two slots through a gate or passage cut in the bar at right angles to the slots. A lever works backward or forward in either of these slots and can be shifted from one to the other through the communicating gate. The ends of the slots represent the positions of the lever when certain gears are engaged, and in the illustration, Fig. 13, the lever is seen with the third or high gear in mesh. For changing from third to second gear the procedure is shown graphically. The first position is with the clutch engaged and the gear lever in third gear position, the clutch being shown above the grid. The second position shows the clutch disengaged and the lever being moved toward the second gear position, marked 2 on the grid. The third shows the lever in second gear position and the fourth, the final step in the change, the clutch again engaged. The procedure is the same in the case of a progressive sliding gear.

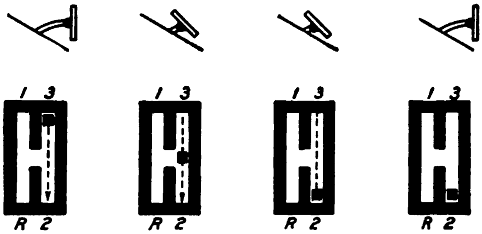


Fig. 13. Movement of Clutch Pedal (top) in Changing from Third to Second Speed (bottom).

Changing from Second to First Gear. Fig. 14 shows the change from second to first gear on the same grid, the upper line of figures showing the movement of the clutch pedal and the central line the corresponding movement of the accelerator, or throttle. The first position shows the clutch in and the throttle open ready for the change: the second shows the clutch withdrawn and the lever moved along the slot until opposite the gate; while the third shows the lever being moved through the gate and along the other slot toward the first gear position, this sideways and forward movement being combined in one continuous movement. The motor having speeded up as soon as the clutch is released, it is necessary to reduce its speed somewhat before engaging the second gear, so the accelerator is shown partially released in this position. The gear is then engaged, the clutch let in, and the accelerator again depressed, which is the situation shown in the fourth position. A change from first to second is made in the reverse order, except that the accelerator pedal is not released unless it is necessary.

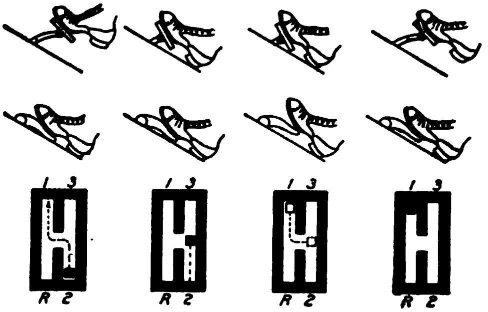


Fig. 14. Movement of Clutch Pedal (top) and ccelerator (middle) in Changing from Second to Low (bottom).

Use of the Spark. Upon the proper use of the sparking device depends the economy of the motor, and in many cases the safety of the driver. On some cars the sparking point on the magneto is fixed, and the autoist controls the car by the throttle only. There are a number of cars in use which employ the battery in connection with separate coils or a single spark system, or a magneto on which the spark can be regulated by the driver. When starting, the spark—in the case of battery ignition—should be retarded to prevent back-firing, and—in the case of magneto ignition—should also be retarded to a certain point, depending on the motor and magneto. When it is desired to slow the motor down below the point obtained by throttling only, the spark is likewise retarded. In ordinary running, a position of the spark lever can be found which will give fair average results through a considerable range of speed without changing its position, and this position varies with each motor and can be found by experience. When a higher rate of speed is desired, the throttle is opened and the spark advanced gradually. If a grade is to be negotiated it should be "rushed" if possible, the throttle being opened full and the spark well advanced until the motor begins to slow down and "knock," when the spark should be retarded to correct this. The autoist should always keep the spark as far advanced as possible, without causing the motor to knock. When accelerating or retarding, the spark should follow the throttle, the latter always being operated first.

Driving at a Constant Speed. One of the best lessons on the proper method of driving a car is that of driving at a constant speed, no matter what the road conditions. The autoist should previously determine a speed compatible with the nature of all roads over which the car is to pass, and should see that the speedometer hand keeps at the determined speed throughout, regulating the spark and throttle and changing gears if necessary. Considerably more will be learned about the flexibility and power of the motor by driving in this way for a few times than by driving many times in the ordinary way.

Reversing is Usually Neglected. Among other things connected with driving which is apt to be neglected is reversing or driving a car backward. Usually a car is never reversed for more than a few yards at a time and the maneuvering involved requires no great skill. Steering a car when running backward is diametrically opposite to that when running forward. A turn of the wheel to the left steers the car in the opposite direction, to the right, and *vice versâ.* The usual mistake made in reversing is in turning the steering wheel too far and describing zigzags in the road as a result. The autoist should remember that *the reverse gear of a sliding change gear should never be engaged until the car has been brought to a full stop.*

Systems of Control. Shifting a gear lever and pressing a clutch pedal does not constitute all that has to be learned about the control of a car by any means; in fact, to be frank, it is just a beginning. Each single action is of itself simple, as the sliding of gears, and the action of throwing out a clutch. So, too, is the throwing on of the brakes and the movement of the spark and throttle levers, but the really hard part is when it becomes necessary to do all of them simultaneously, that is—throw out the clutch, drop into low speed, throw on the brakes, shut down the throttle, and retard the spark: six complete and decidedly different actions at once, if both brakes be used.

As exemplifying the ordinary cases, several typical control systems will be shown and explained. The first, illustrated in Fig. 15, is that of the Chadwick car, a very large and powerful machine.

This has no less than ten components to the control system. First, there is the steering wheel, which governs the direction of the machine; second, is the speed lever, which controls the speed at which the machine can travel; third, is the emergency lever outside of the speed lever, and the most prominent in the illustration; fourth, is the clutch pedal, the one on the left; fifth, is the service brake foot pedal, which is placed at the right side of the foot board; sixth, is the foot accelerator, which is used to impart to the engine a sudden burst of speed, such as is necessary sometimes to cross a street ahead of a team—this is

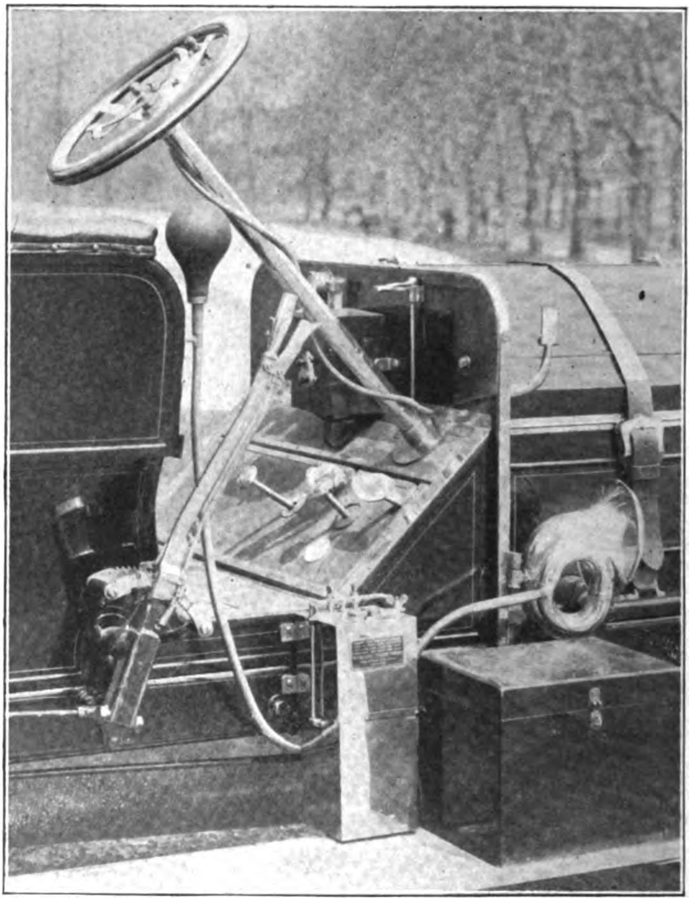


Fig. 15. Complete Control Mechanism of the Chadwick Car.
Chadwick Engineering Works, Pottstown, Pa.

located at the back of the right foot, so as to be manipulated by the heel of that foot when in its usual place upon the brake pedal; seventh, is the muffler cut-out, which is a very effective and rapidly working signal to teams and others in the street ahead; eighth, is the toe switch, by means of which the ignition may be cut off entirely; ninth, is the spark advance lever, which is placed with the tenth, the throttle lever, upon the upper interior part of the steering wheel. It is also obligatory upon the driver to sound the horn at all crossings, so that this might be put down as the eleventh item. So, the poor novice is bewildered with no less than eleven things to control at once, to say nothing of the motor itself, or its ignition, water supply, and numberless other parts which might not work—in which case, the motor might stop or if it continued to run, might be ruined. Thinking all of these things over it is apparent that there will always be some people who will not and cannot learn to drive.

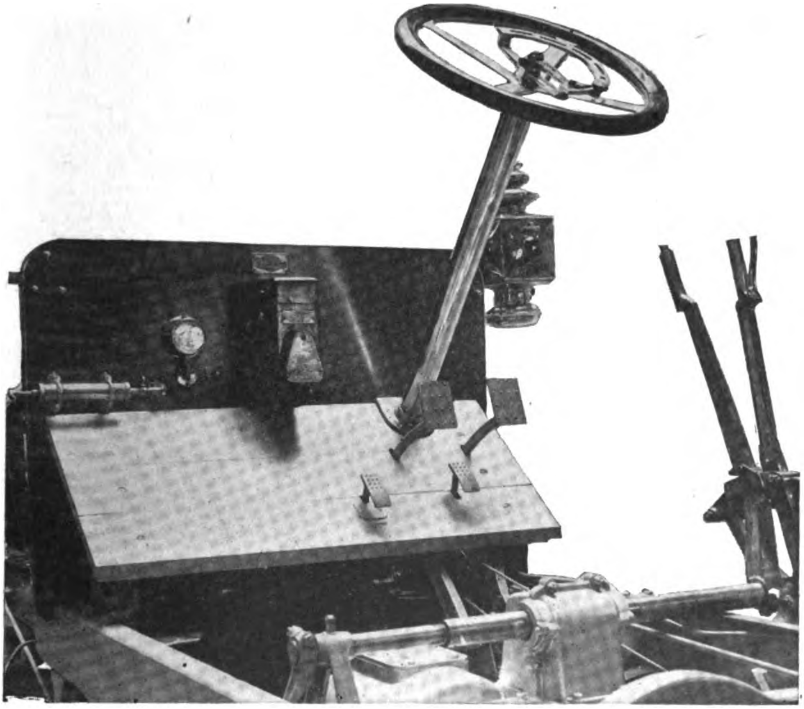


Fig. 16. Dashboard and Control Parts of the 40-H. P. Palmer-Singer.
Palmer-Singer Mfg. Co., New York City.

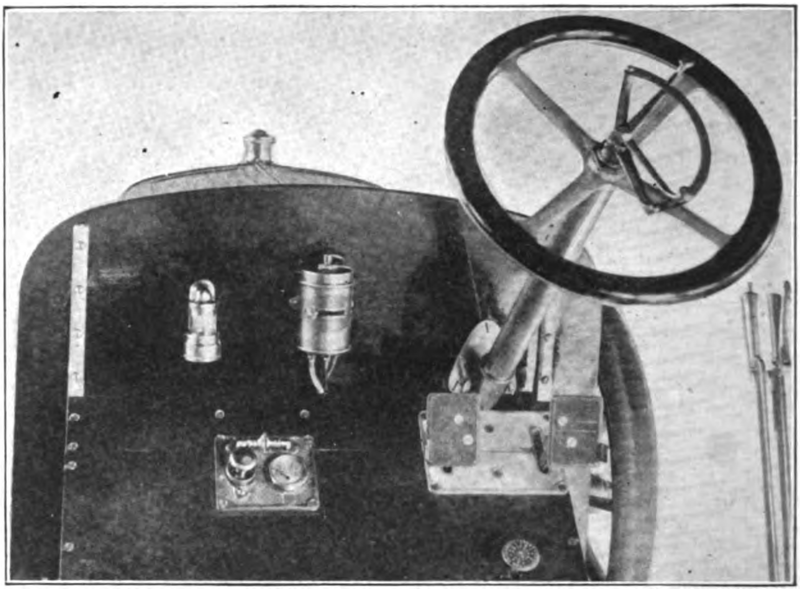


Fig. 17. Dashboard of the Lozier Little-Six.
Lozier Motor Co., Plattsburg and New York City.

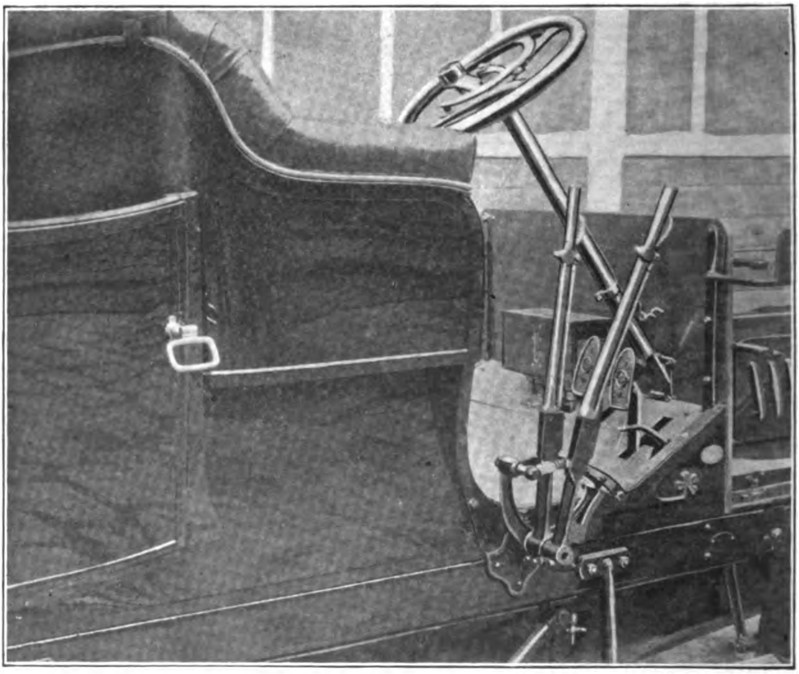


Fig. 18. Control Levers on the French Brouhot Car.

Another control system and its operating means is shown in Fig. 16, which represents the dashboard view of the P & S 40-horsepower machine made by the Palmer & Singer Mfg. Co., New York City. This differs little if any from the Chadwick, aside from the change in the spark and throttle levers, which are here placed so as to be operated by the right hand rather than by the left. All pedals have a rectangular section, but the mode of operation is the same. As differing a little more than this, the Lozier control, Fig. 17, is offered. In this it is seen that one pedal, the muffler cut-out, as well as the foot accelerator of the Chadwick, is missing. In its place, however, there is a foot pump to maintain the oil pressure, this being seen at the left. To turn now to a foreign car, a marked difference is seen, as exemplified by the Brouhot car, Fig. 18, and the Rochet-Schneider car, Fig. 19. This latter shows three foot pedals of equal size, thus giving the muffler cut-out equal importance

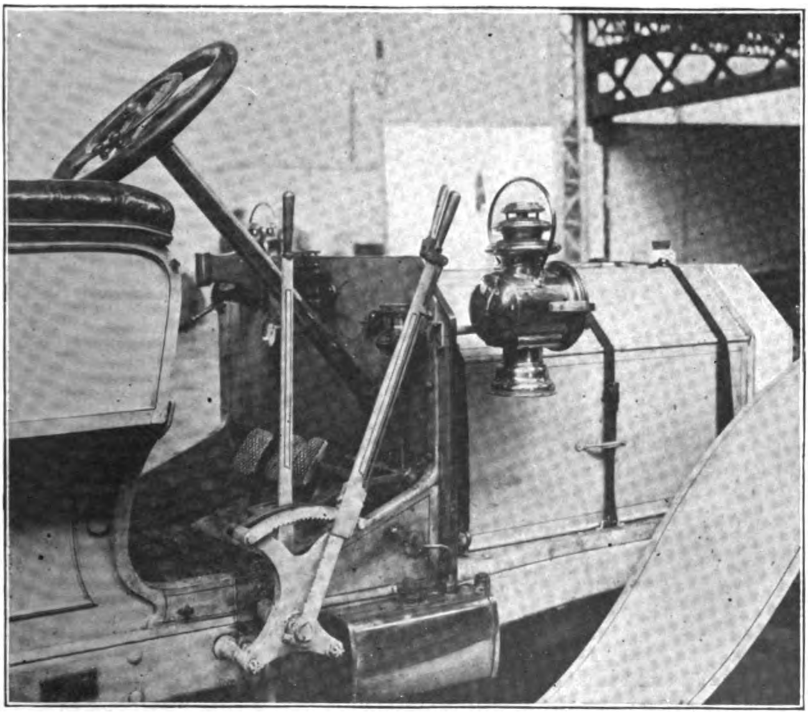


Fig. 19. View of Rochet-Schneider Car Showing Square Foot-Pedals.

with the clutch and service brakes. In addition, there is the foot accelerator, a smaller, lighter pedal at the extreme right. A hand lever on the dash may be used to increase the fuel pressure at any time.

Simplicity of Control. Nowadays, simplicity of control and the appearance of the dashboard are very essential features, and of value in selling a car. On the Franklin, Fig. 20, this is seen to have been attained. There are but two pedals and two levers, besides the usual throttle lever. On this car, the spark lever has been omitted, owing to a special design of magneto. In many cases, the use of a pedal is said to be an easier, more natural act than the use of a lever

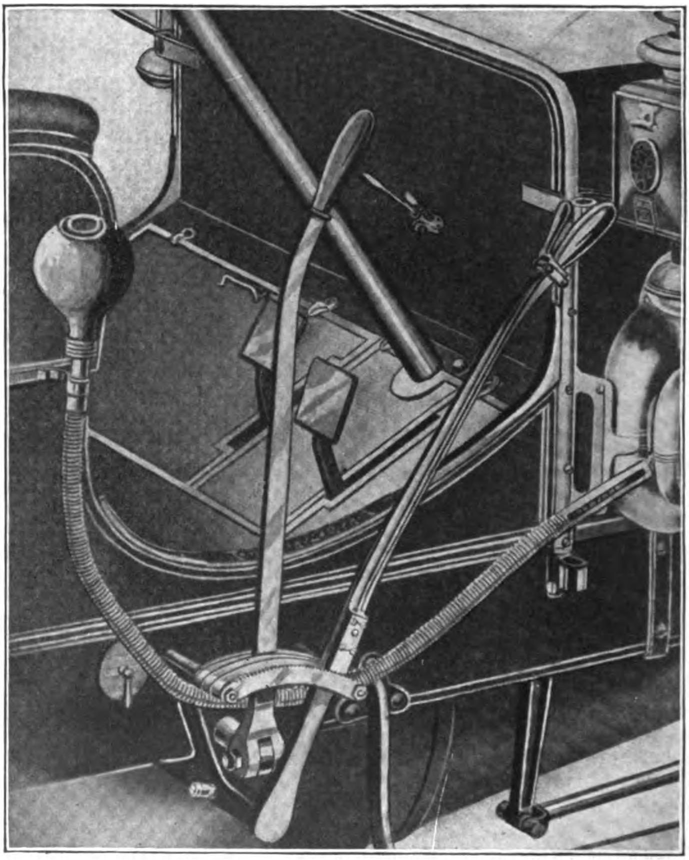


Fig. 20. Clean Dashboard a Characteristic of the Franklin Car.
H. H. Franklin Co., Syracuse, New York.

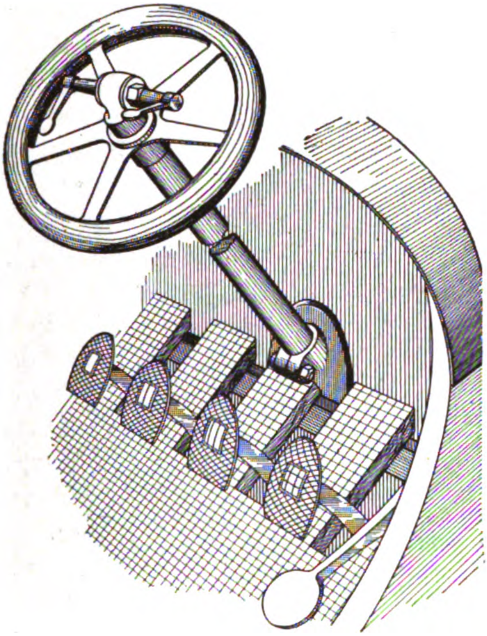


Fig. 21. View of the Adams, an English Car. No Side Levers.

operated by the hand. Taking full advantage of this fact, one English car, the Adams, uses pedals only, all levers being eliminated. Thus,

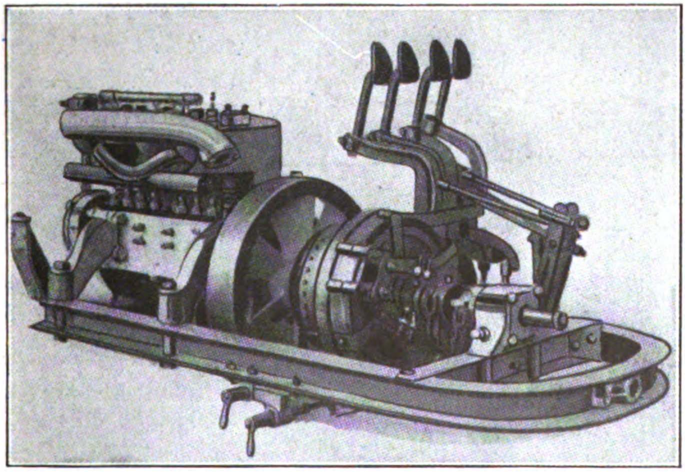


Fig. 22. Power Plant of an Adams Car.

as Fig. 21 shows, there are no less than five pedals to operate on this car. These are, respectively from left to right: reverse or brake, low speed, second speed, high speed, accelerator. The smaller cut, Fig. 22, shows how the connections of the pedals with the power plant are made. Not all hand levers act alike, as is brought out by the picture of the Stevens-Duryea control levers, Fig. 23. In this, it will be noticed that there is a small pin in the change speed lever, which slides in a slot. Normally it drops into a depression and holds the lever in place. To move the lever, it is necessary to raise this out of the groove. The smaller figure alongside of the levers shows just how this works.

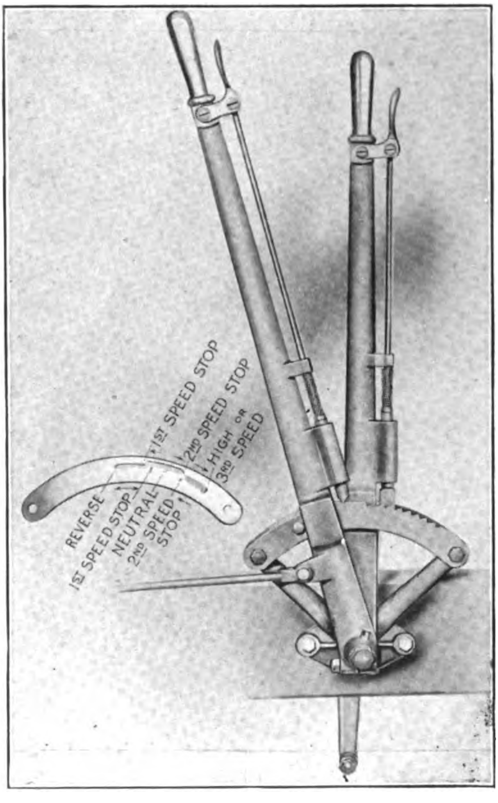


Fig. 23. Side Levers on the Stevens-Duryea Car.

As the method of imparting the use and action of these various parts to a novice is of some value, all of the schools teach it in a very thorough manner. Fig. 24 shows a scene in a Parisian school, L'école Centrale de Paris, where the instructor is demonstrating to some students the operation of the control pedals and levers, as just explained. One of the students is working the muffler cut-out. The car is a 40-horse-power Peugeot. Equally important is the actual application of this knowledge to the operation of a car. The way in which the latter is imparted is illustrated in Fig. 25 in which an instructor is showing a student how to change gears.

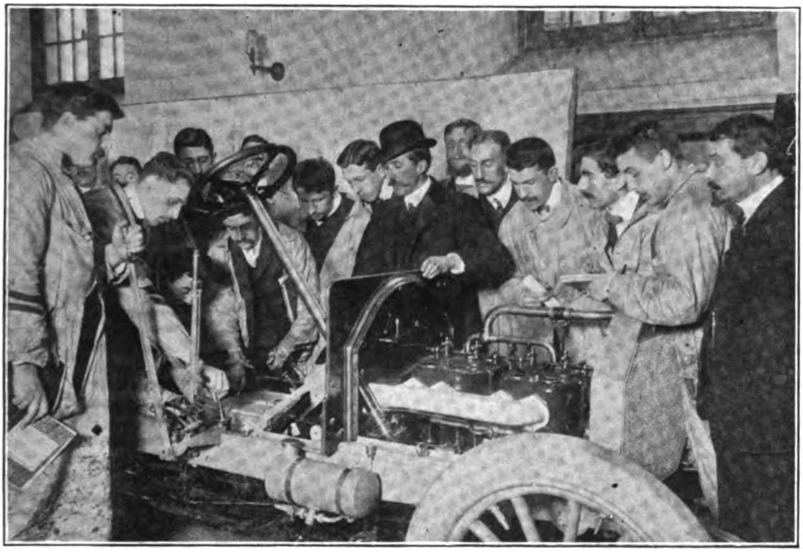


Fig. 24. Scene in a Parisian Automobile School.

STEERING GEAR

Mention has been made several times of the steering gear, and this plays a very important part in the operation of a car. Fig. 26 is a good illustration of the Peerless steering gear, and although it does not reveal the internal construction of the gear, it shows the operating lever at the base, the motion of which results in the movement of the wheels. The spark and throttle levers which connect directly to the magneto and carbureter respectively are seen, one below the gear, and the other near the top of the casting which holds the gear to the dashboard.

Fig. 25. Shifting Gears.

CLUTCH

One of the most puzzling sources of trouble is the clutch. The reason for this lies in the fact that it is seldom described to the novice,

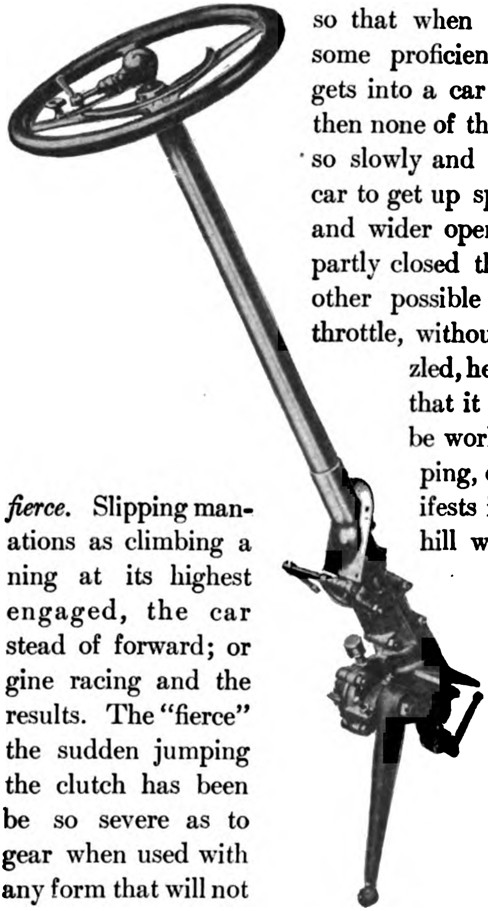


Fig. 26. Steering Gear of the Peerless Car.

so that when he thinks he has assumed some proficiency in driving, some day he gets into a car with a slipping clutch, and then none of the little things he has learned so slowly and painstakingly will cause the car to get up speed. He tries more spark and wider opened throttle, less spark and partly closed throttle, and all of the "57" other possible "varieties" of spark and throttle, without any result. Sorely puzzled, he appeals for aid, and is told that it is the clutch. This may be working properly, it may be slipping, or it may be what is called *fierce*. Slipping man- ifests itself in such pleasant situations as climbing a hill when, with the engine running at its highest speed and the proper gear engaged, the car starts to run backward instead of forward; or on the level, with the engine racing and the high gear in, no speed results. The "fierce" condition shows itself in the sudden jumping forward of the car when the clutch has been let in, and it may even be so severe as to shear off the bevel driving gear when used with studded non-skid tires or any form that will not slip easily.

To repair the slipping clutch, see if the surface of the leather is in good shape but has lubricating oil on it. If so, wash the surface well with gasoline, and roughen a little with a coarse file.

The harsh or fierce clutch is remedied by the application of a proper oil for this purpose. Castor oil is universally used and a good way is to soak the complete clutch in it over night. This will cure a case of harsh leather, but it may be that the trouble is only a lack of adjustment of spring tension. Usually there is an adjusting nut and a locking nut. Back off the latter and make an adjustment, then tighten the lock nut to retain it. For the beginner, it is better to adjust a little at a time and make several successive jobs of it than to try to do it all at once. But always adjust it as soon as possible.

CHAINS

While there are not as many chain-driven cars as there were formerly, still there are now and always will be a number of the highest powered cars driven by the double-chain method. This is an efficient drive, mechanically considered, but has fallen into disfavor, because of its noise and dirt. Both of these, however, can be reduced to a minimum.

The owner or driver of a chain-driven car should learn very early in his driving career to care for the driving chains in a proper manner. While chains have been known to run an entire season without any care or additional lubrication, this practice is to be deprecated. To care for a chain properly, one should get into the habit of lubricating it at such intervals that they occur before the chain is in need of the oil. In addition to this regular lubrication there should be some set time at the end of which the automobilist takes the chain off, cleans it thoroughly, and inspects it in order to detect faults. A month is a good length of time for this. An excellent way to proceed is to take the chain off and let it soak in a pan of kerosene over night. By morning, all of the dirt will have passed from the chain to the liquid and can be found at the bottom of the pan. Clean the pan and put the chain in it and wash off with gasoline all traces of the kerosene. Having done this, hang the chain up to let the gasoline evaporate.

The chain then will be both clean and dry. Now inspect all rollers, links, rivets, and bushings, taking note of any unusual wear as indicated by looseness or play. If defects are found, they should be remedied. Then, having the chain clean, dry, inspected, and passed upon as O. K., an excellent method is to soak it, or, better, boil it in a heavy melted lubricant. The best quality of beef tallow mixed with a little graphite is good. Many do not like the latter, in which case a high-grade oil may be substituted.

LIGHTING SYSTEM

Any part of the car liable to be put to use should have intelligent care. Thus, the lighting system is used only at night, but should be kept in first class order at all times, so that when night falls, the whole system will be ready to go to work at once.

Care of the Generator. The interior of the carbide chamber or basket is more or less in contact with the water distribution apparatus and the parts of both apparatus are liable to clogging by the formation of lime residue in the generation of gas. If this residue is allowed to collect, it will have to be removed with a chisel, which is a ticklish operation in a light construction like that of a generator, especially around the water valve or its outlet. Acids are sometimes used to remove the deposit, but as they eat the metal, their use should be prohibited. The basket and pot should be thoroughly washed out after each run with water, the water outlets being cleaned with special brushes, when these are obtainable, or by wires, to remove all traces of lime. The water valve should be scraped and tested to see whether it seats properly, care being taken not to damage the valve or its seat in so doing. While the valve is dismounted for cleaning it would be well so see that its stem is straight and that it works with some ease in the threaded portion attached to the water chamber. The gas valves should be cleaned and should seat snugly, so that there will be no leakage past them. This applies also to the gas valves on the lamps.

The best position for the generator is on the running board just back of the change-gear quadrant, and sufficiently far out from the frame to allow a free circulatoin of air all around it. The generator will keep cool in this position and will perform its work to the best advantage when properly cooled.

The Much-Neglected Condenser. When used at all, the condenser or its substitute is put off in some position where it becomes caked with mud and is almost forgotten until it is full and the lamps begin to flicker. Then the mud is cleaned from it and it is drained out. It should be placed so that it is close to the lamps, where it will catch all of the condensation from the gas going to the burners, and in addition any water that may enter the burners due to washing of the car. It should be emptied from time to time, say once or even twice a month, when the lamps are in regular use. The majority of troubles with acetylene lamps are due to lack of a condenser and to the use of too small metal tubing.

Regarding Tubing and Gas-Bags. Copper tubing is considerably used for piping the gas to the burners, but it is liable to erosion by the gas, and standard ⅛-inch iron gas pipe is better and lasts longer. The gas-bag and rubber lamp connections should be kept clean and not painted, as is often done to correspond with the car, as paint rots the rubber, with the result that it is soon unserviceable and must be replaced. When the rubber is to be washed, only water should be used and the goods should be carefully dried before putting them in service again.

Care of the Lamp. It goes without saying that the burners should be kept clear, wires being passed through the gas apertures and the air apertures at intervals. The burners should be unscrewed occasionally, air blown through, and the interior of the burner body scraped clean of deposit. Outside of keeping the lenses and glasses bright and polishing the exterior of the lamp, there need be no other attention paid except to keep all joints and the bracket screws or nuts tight.

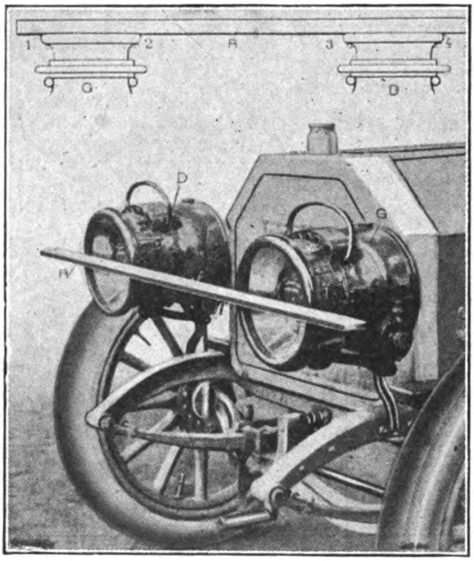


Fig. 27. Method of Aligning Lamps.

Caring for Acetylene Lamp System. As there is little night running during the winter months, the acetylene lighting system is more or less neglected, the generator being left with stale or partially used carbide in the chamber, and the residue being allowed to clog up the water port and the waste ports. The rubber lamp connections and gas-bag suffer also by deterioration as well as the burners and gas valves. For the proper maintenance of the system, strict cleanliness should be maintained at all times and the various parts should be examined and replaced from time to time as necessary. The results of neglect are seen every spring in lime deposits which have to be removed by means of a cold chisel, in porous connections, and in clogged burners which resist the cleaning wire and necessitate the scraping of the burners. By following the accompanying directions, the automobilist can depend on having his lighting system in good shape whenever he desires to use it.

Lining up Lamps. If there is anything which is more noticeable than lamps out of line, *i. e.*, one farther forward than the other, the writer has failed to notice it. Drivers can avoid this "sloppy" appearance of their cars by simply taking a five-foot straight edge, and lining the lamps up in a proper manner, Fig. 27. This does not need to be done often, for the lamps do not work out of position, so if well done at first, it will always appear well. Since the lamps have considerable breadth, and may be assumed to be made square, by placing one and fastening it, the straight edge will indicate the proper position of the other. With that placed, the straight edge may be called upon again, to decide if they line up correctly. If they do, tightening the bolts locates the lamps so that they not only look right but are right.

ROAD REGULATIONS AND PRECAUTIONS

Early in his driving career the novice should cultivate a sense of fairness toward other drivers of automobiles, toward vehicles other than automobiles, and toward pedestrians. There is too little of this, and it may be said without fear of contradiction that this absence has done much in the past to retard the development of the automobile in rural districts; in fact, it has brought out a feeling of antipathy there which is but now being dissipated.

Passing Horses on the Road. The majority of horses encountered on roads frequented by automobiles to any extent, pay comparatively little attention to them, even when passed at fairly high speed, and of the remainder it is safe to say that most are not nearly so alarmed as their drivers, who communicate the alarm to the horses through sawing on the bit, shouting, or dropping the reins. The exceptions are young horses or those which have not been given sufficient road driving. In passing horses, the autoist should not only observe the actions of the horse, but also those of the driver. If the horse exhibits signs of being restive, the voice has a very quieting effect. Expressions such as "Whoa, boy." said in a reassuring tone will, in many cases, be sufficient to soothe the animal until the car can pass.

The best manner in which to pass a standing horse headed in the same direction as the car is to cross to the far side of the road and drive by quietly at the legal speed. The horse will be only slightly startled, if at all, and will not bolt or back, as the alarming object and its terrors are gone. More care is necessary in passing a horse headed in the opposite direction, as the animal can see the car coming and has time to become fidgety. If the driver has the animal under control, the car can be driven past at the regular pace unless signs of fright are seen, when the car should be slowed down, or stopped if necessary. The car should pass on the opposite side of the road and as soon as it is by, speed can be increased in order to get out of hearing as soon as possible.

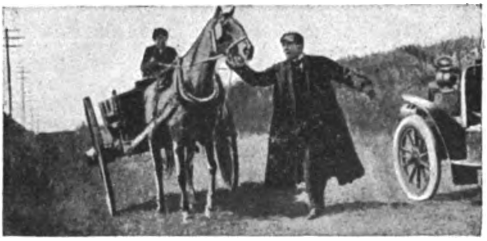


Fig. 28. Correct Method of Leading a Horse.

Procedure in Leading a Horse. It may be necessary in some cases to stop both car and motor and to lead the horse past the car. A number of accidents have occurred in so doing by the horse freeing his head from the bridle through improper leading. Both reins should be taken in the right hand, Fig. 28, about 6 inches from the bit and the horse patted and reassured by the voice. The autoist should then *face forward* and start off, walking alongside the horse's head until past the car. Should the animal rear, the grip on both reins prevents him from tearing free from the bridle and bolting. The usual mistakes made in leading are in grasping one rein only—which hurts the horse's mouth and may break the bridle—and walking backward while leading the horse along. As a horse will not willingly walk over a man and as this is the position usually assumed by drivers when hitting the animal over the head, the operation instead of having a soothing effect, alarms and confuses him. Another situation requiring care is shown in Fig. 29.

Caution Needed in Overtaking Vehicles. There are two general principles to be remembered in overtaking or passing vehicles on the road. These are: Be sure that there is a clear way ahead before the overtaking or passing is attempted, and never cut things so fine that a swerve on the part of the other man will cause a mishap. Quite a large proportion of road collisions come from either of the parties concerned taking chances that the other will do the right thing, which seldom happens. In overtaking another vehicle, care should be taken to ascertain that the driver is aware of your presence, particularly if he is driving a covered vehicle or one that is noisy. It is often difficult to make the other man hear, and the chances of his swinging out are too great to warrant any risk being taken. A tendency on the part of the driver to turn off to the side of the road, apparently to let the autoist go by, may be the result of an involuntary pull on the reins or may have been done to avoid a bad place in the road, and this turning off is often followed by an equal swing in the opposite direction. In following a vehicle the autoist should not keep in the other vehicle's tracks, but should stand off diagonally so that he or one of the passengers in the car can see the road ahead and observe the actions of other vehicles. Sufficient distance should be kept so that the autoist can turn in behind the leading vehicle in case of the sudden appearance of others coming in the opposite direction. When the way ahead is clear, the autoist should pass as quickly as the nature of the road permits.

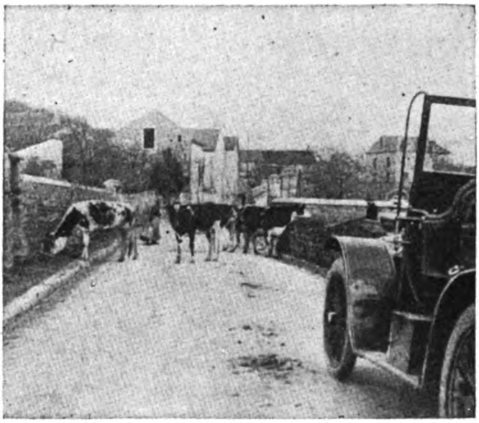


Fig. 29. Passing Cattle on a Country Road.

Passing Moving and Stationary Vehicles. The chief point to be remembered in passing moving vehicles is to always allow plenty of room for both. The passing of another vehicle so closely that there is hardly room for a sheet of paper between them, may be looked upon as brilliant driving, but sooner or later some one will miscalculate and an accident will occur. All passing should be done according to the rule of the road prevailing in the section of the country in which the car is being driven, as the great majority of road users follow this rule, and in case of accident the vehicle which held to the proper side of the road is generally exonerated in the courts. In passing stationary vehicles or those about to start, a strict lookout ahead should be kept for pedestrians or vehicles suddenly emerging from the rear, or in the case of a trolley car, for alighting passengers and those rushing to board the car. It is not sufficient to blow the horn and count on its being heard by those behind the other vehicle. The chances are that the sound has not been heard, and nothing but slow speed can be indulged in with safety. The same need of slow speed and extreme caution occurs in overtaking stationary vehicles as in passing them.

Passing on the Wrong Side. As a rule, all vehicles should be passed on the proper side according to the rules of the road, but there are occasions when it is unsafe to pass in this manner and the autoist has either to pass on the wrong side or to wait until conditions are such as will allow him to pass according to rule. Such an occasion often presents itself in overtaking a heavily loaded vehicle or one which has been disabled and has not been withdrawn to the side of the road. Once a loaded van or truck leaves the crown of the road, it has some difficulty in getting back again, especially if drawn by horses, and the driver will generally refuse to turn aside except for other equally heavy vehicles. As the autoist is conducting a vehicle of superior speed and mobility to that of the truck, the latter can be considered as a stationary object for the time being and passed on the wrong side, provided the road is clear. The situation is shown in the sketch, Fig. 30, where *B* is a truck and *A* is a car about to pass the truck. The road being clear, car *A* can take the course *b*, passing the truck on the wrong side. Should course *b* be taken, a collision is likely to occur between the car and another car *C* proceeding in the opposite direction, unless great caution is exercised by both drivers. If there is any doubt as to the road not being clear, the autoist should take no chances but wait until the way on the left of the truck, course *a*, is clear and then pass on the proper side. Situations like the above occur from time to time on the road and the autoist should use his judgment in coping with them. Legally it is not justifiable to depart from the rules of the road except to avoid accidents, and this should be borne in mind at all times.

Proper Negotiation of Road Crossings. In approaching road crossings the autoist should slow down to a speed at which he can pull up on the brake within the length of his car, and blow his horn for the purpose of warning other road users of his presence. As the car approaches the crossing, a sharp lookout should be kept for traffic on the intersecting road, and as soon as the way is seen to be clear the crossing should be taken as quickly as possible. Particular care should be exercised at crossings where one road is partially or totally hidden from the other until the crossing is reached, especially in the smaller towns, as light carts, bicycles, or, in fact, vehicles of any kind frequently emerge from the side road at speed and in the most careless manner, even when those in control are unable to see anything that is approaching on the main road. In anticipation of such performances the car should be kept to the center of the road so as to be able to turn aside to avoid a collision, for if the horn has been blown, there is no way of knowing that the driver of the other vehicle has heard it. Even if vehicles on the intersecting road can be seen, great caution must be exercised, as there is no indication that they are going to continue along the side road nor in which direction they will turn into the main road. Passing partially hidden road crossings at speed is absolutely dangerous because of the long chances which reckless autoists take at such places.

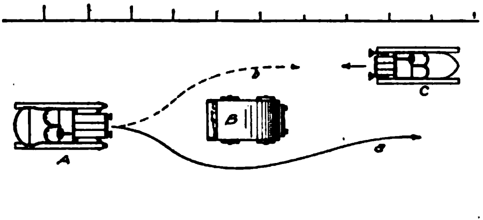


Fig. 30. Case Where Passing on the Wrong Side is Excusable.

On Approaching a Blind Turn. Frequently encountered in suburban towns is the blind turn, where a cross street or road terminates in one of the main roads and the view from either road is obscured by buildings or fences until the turn is reached. At such turns the chances of accident are greater than at road crossings, as at these latter places an autoist has three directions in which he can turn to escape collision, while at blind turns there are but two, with the chances in favor of the car on the side road. Referring to the sketch, Fig. 31, *A* is a car about to enter the main road and proceed thereon in the right-hand direction, and *B* and *C* are cars coming along the main road. Owing to the high fence on one side and the building on the other, *A* cannot be seen from *B* or *C* until the lines *ax* and *bx* are reached, neither can *B* nor *C* be seen from *A*. The sound of a horn from either road likewise cannot be heard from the other. Under the circumstances, car *B* should keep to the center of the road as in negotiating road crossings, and car *C* should keep to the right-hand side of the road and proceed cautiously. When the car *A* makes the turn into the main road, it should take the path shown by the dotted line, swinging well out to avoid a possible collision. Car *B* has thus an opportunity to turn aside and avoid *A*. Should *A* turn to the left into the main road, car *C* is in no danger even if the driver of the former car cuts the corner closely. The positions shown in the sketch should be assumed at all times when approaching a blind turn whether the presence of a car on the other road is known or not.

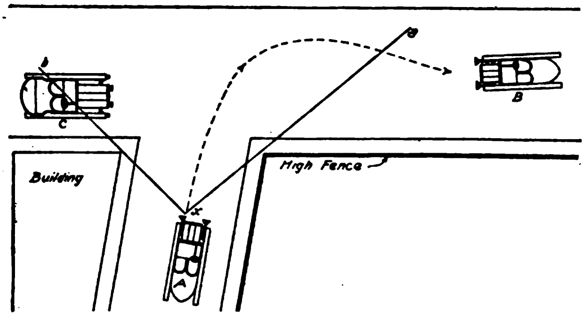


Fig. 31. How to Negotiate a Blind Turn.

The French experts consider the above an excellent argument in favor of the left-hand location of the control, *i. e.*, the driver with all of the steering and controlling mechanism located on the left rather than on the right. The way the argument goes is like this—a man sitting on the left can see farther around a blind turn like the one just described than a man located on the right. Therefore the driver placed at the left would be able to avert a fatal collision more easily.

Be Careful Not to Get Boxed. In keeping religiously to the right when not passing a vehicle ahead—in which case the turn is to the left—the driver should be wary about being caught between a vehicle ahead and the curb stone. Fig. 32 illustrates just such a contingency. As shown, the driver waited too long before turning out to the left, and so will have to stop and back away before he will be able to pass the obstructing wagon.

The Right of Way at Turns and Crossings. Regarding the right of way at turns and crossings, the vehicle which arrives first has the priority of passage according to actual road practice. In case of a "dead heat" between two cars, it remains for both drivers to agree as to which shall proceed ahead of the other, the driver yielding the way giving a signal with the hand. Generally speaking, horse traffic gives the precedence to automobile traffic as a matter of safety, but the autoist should not consider that he has the absolute right of way over all other road users for this reason. All users have equal rights on the road, but because the autoist has a vehicle of great physical superiority due to its weight and speed, he is not entitled to lord it over those not so well equipped. It does no harm to yield the road to a horsed vehicle even if the action necessitates a change of gears or a stoppage of the motor. On the contrary, the courtesy shown will do much toward removing the prejudice against automobiles in that portion of the country. In general, the autoist should exercise his discretion as to what is proper under the circumstances, departing from road practice if necessary, and his individual sense of fair play should cause him to have regard for the rights of others at all times.

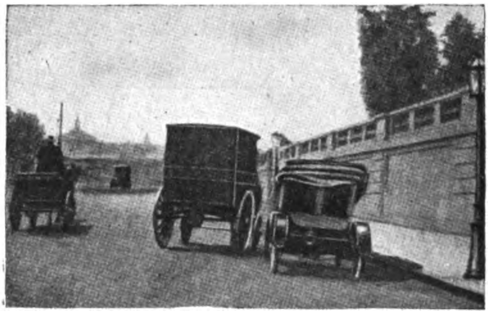


Fig. 32. Result of Running too Close to Other Vehicles.

Negotiating Turns. The procedure on approaching a turn is exactly similar to that on approaching a road crossing. The car should keep to the center of the road and its speed should be reduced somewhat until the road is seen to be clear when the turn can be made. In taking a right-hand turn, the autoist should keep well away from the corner, describing as large an arc as possible and gradually gain-ing the center of the other road. Such maneuver is shown in the sketch, Fig. 33, where the car *A* follows the dotted course until the point *b* is reached. By so doing a collision with another car coming in the opposite direction will be avoided as either car can swing clear. In taking a turn to the left, a similar maneuver should be made, but in this case the car should keep close to the proper side, as in the sketch of the left turn. The size of the arc described in making the turn will, of course, depend on the width of the road and the length of the car, small runabouts being able to turn in an arc of 25 feet or less, while large touring cars should describe arcs of 32 feet and over on an ordinary road.

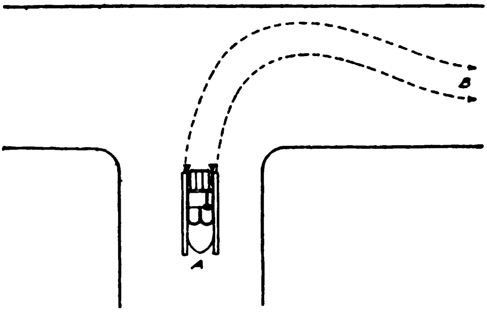


Fig. 33. Proper Turn to the Right.

Corner Shaving to Be Avoided. Except when absolutely necessary to avoid a collision, corners should never be cut closely or "shaved" as it is often called. By shaving a corner the autoist runs chances of colliding with other vehicles, and engenders a dislike in all other users of the road not only for himself but for automobiles in general. There are numbers of drivers that habitually shave corners, who start to make the turn before reaching the proper point and cut diagonally across the road, obstructing traffic coming in the opposite direction, and hugging the left-hand corner of the intersecting road. Their desire is evidently to travel from one point to another in the shortest possible space of time, and, to save distance, cut the corners without regard to the rights or safety of others. The majority of automobile drivers of this class luckily confine their operations to city streets, although they are found in some numbers on country roads. On the other hand a large majority of horse drivers are corner shavers, women being particularly given to the practice. Because of the presence of this and the reckless classes of drivers, special caution has to be exercised at all times by those in charge of vehicles of every kind, Fig. 34.

On Approaching a Road Fork. On approaching a point where the road forks or branches off, the autoist should hold well over to the proper side of the road in order to avoid cars coming along the branches. Should he be traveling along one of the branches toward the fork, however, he should keep in the center, as when approaching an ordinary turn. On overtaking another car, it would be better to allow the latter to proceed on its course without attempting to pass, unless the driver signals the direction he is about to take. The reason for this can readily be seen by referring to the sketch, Fig. 35, where car *B* is about to overtake car *A*. If *B* attempts to pass *A* by taking the path *y*, a collision will occur if car *A* turns down the left fork at *a*. On the other hand, if the path *x* on the wrong side is taken, a collision will occur at *b* if the leading car takes the right fork. Hence the driver of *B* should allow *A* to take its course before proceeding on his own. If the driver of car *A* should signal the fork he is going to take, *B* can pass on the proper side if the same fork is to be taken by both, and on the wrong side if *A* is to take the left fork and *B* the right. If *A* is to take the right fork and *B* the left fork, *B* will pass in the ordinary manner.

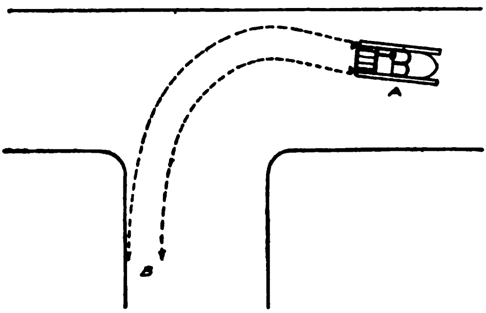


Fig. 34. Correct Turn to the Left.

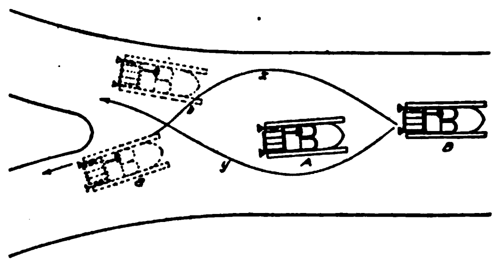


Fig. 35. How to Pass a Car at a Fork.

As stated before, turns should be taken slowly, particularly, close to cities or towns. In the country, one is apt to forget this advice and whirl around the turn as if there were no turn there. An experience with a rapidly skidding car on a turn like the one shown in Fig. 36 will cure the driver of this habit. Here an open and fast road tempts one to speed. The curves are flat, and rounding them at speed, the car would skid to a very great extent and just where the

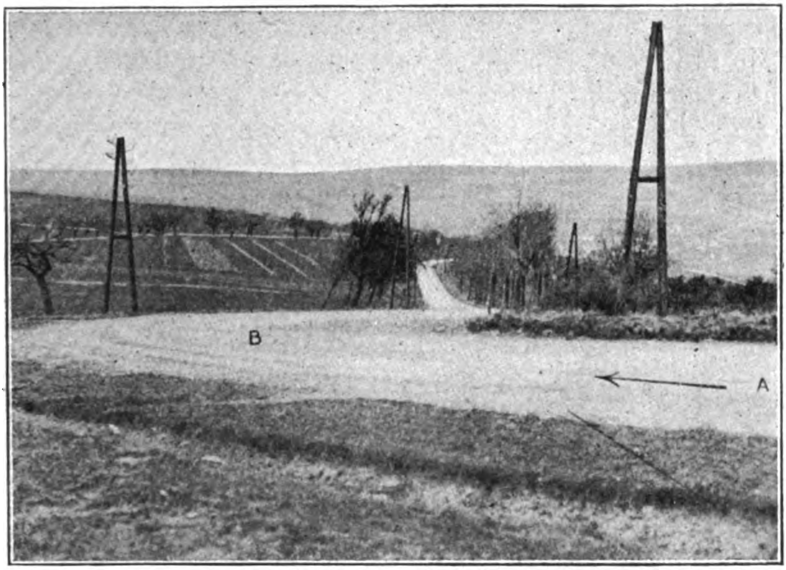


Fig. 36. Bad Turn Requiring Care and Slow Speed.

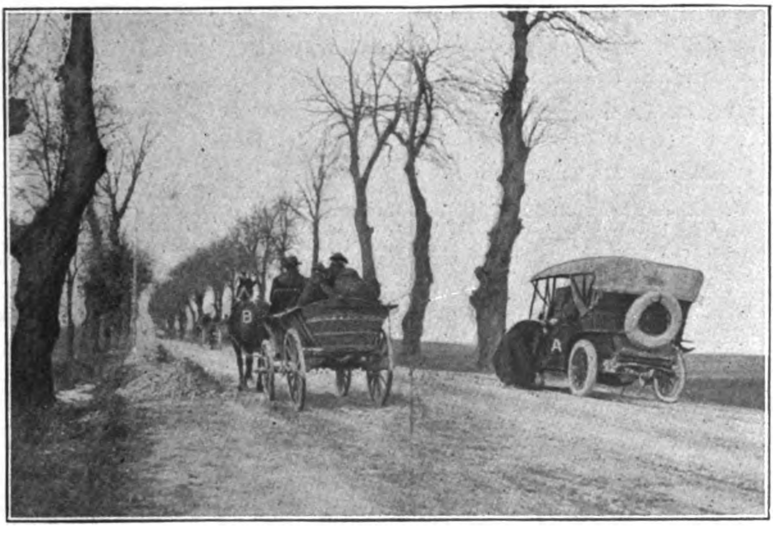


Fig. 37. Road Situation Requiring Slow Speed and Plenty of Warning.

skidding car will be sure to strike will be noticed a nice, soft (?) telephone pole. Another situation requiring slow speed and plenty of warning is shown in Fig. 37.

Under Bridges Sometimes Dangerous. Fig. 38 presents a scene of more than passing interest—one in which considerable danger to the autoist may be lurking. This is a case where a road leads under a bridge and the other end of the road turns away so that it may not be seen. That is, this represents two blind turns, with a bridge added to complicate matters. The proper procedure is to approach slowly, signalling loudly, until well under the bridge, when a slightly improved view of the other road may be had. If another car is approaching, it is an easy matter to stop, and if no other car or vehicle is in sight, it is an equally easy matter to throw on full speed.

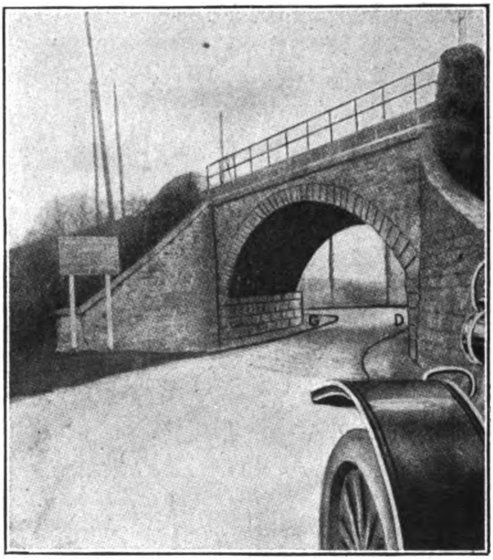


Fig. 38. A Dangerous Road Situation.

Blind Courts Give an Opportunity for Skill. A driver who is skillful in maneuvering around has an excellent chance to show his skill, when caught in what is called a *blind court*. This is, as shown by Fig. 39, a court or street which has but one entrance and exit, the two corresponding. To get out it is necessary to back, come forward again, back and forward, until the car is moved around in the narrow court so as to be able to proceed in the reverse direction. In the figure, the first position is marked (1). From this, the driver perceiving his situation, turns as sharply as possible to second position (2). In stopping, the wheels are warped around in the opposite direction as far as possible, before moving the car—bad practice but needed here to save every inch. Then throwing into reverse,

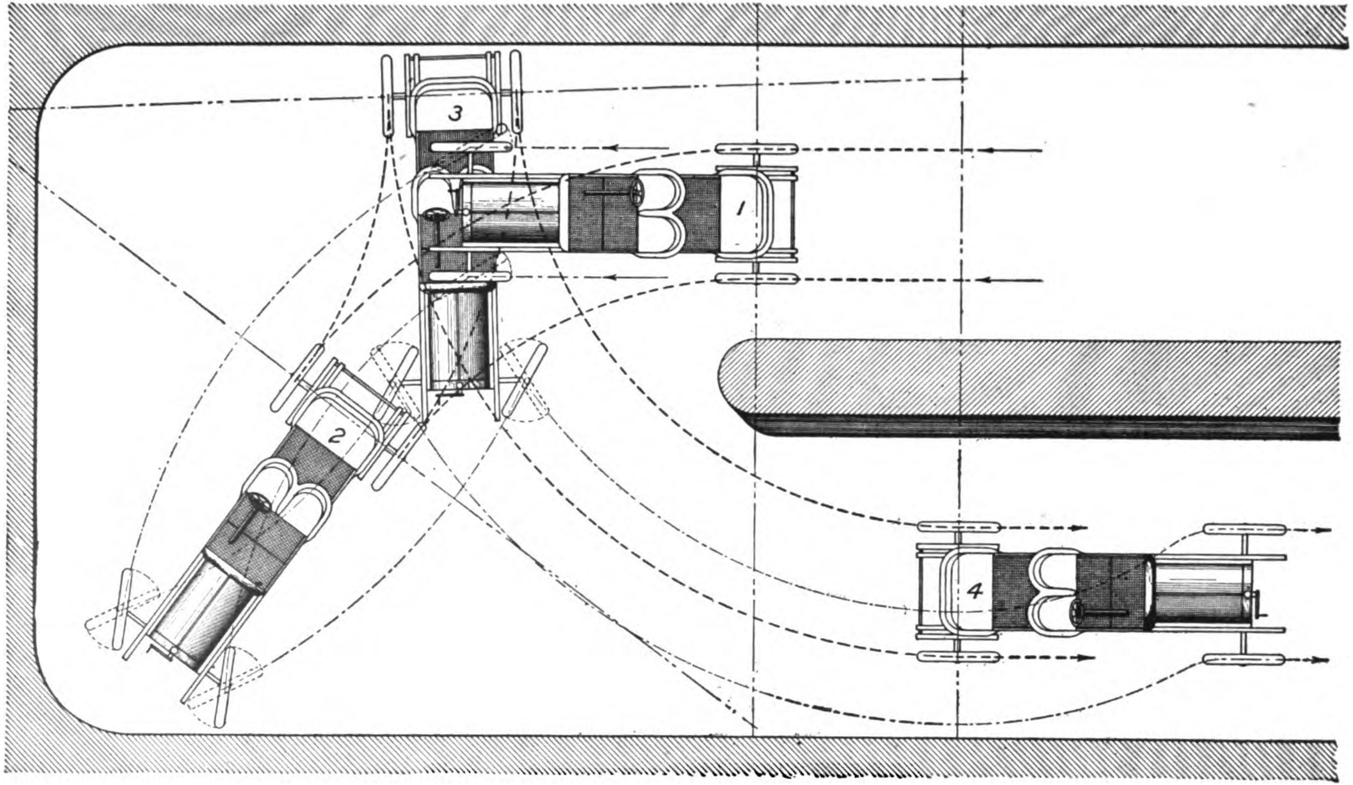


Fig. 39. Maneuvers in Getting Out of a Blind Court.

the driver backs up to the third position (3). From there, by cutting a very close corner, he is able to proceed out of the court. Position (4) shows the final position of the car, while the dotted lines indicate its movements. A narrower court would have called for more backing than this one did.

Volumes could be devoted to this subject, for the situations met with on the road are endless, as are also the combinations of cars, drivers, and corners. The driver should always be fair and render to others their half of the road, their share of time wasted and saved, as well as consider that they might have been as near right as he.

MECHANICAL FEATURES

The driver who wishes to know more about his machine than is necessary to simply run it, or the man who wishes to follow driving as a profession should approach the subject intelligently, and should learn as much about the mechanical side of the work as is possible. There are many ways of doing work, not all of them correct, and the man anxious to get along should learn the right ways. Thus, the subject of valves is very important, since leaking valves prevent the motor from doing its best work, and may even prevent it from working at all. This fault is certainly "up to" the driver of the car, just as much as if he deliberately broke a valve with a hammer.

Grinding the Valves. The new driver must learn when to grind-in his valves, that is, how often, and he must also learn how to do the work properly. There is no hard and fast rule which can be given aside from grinding when it is necessary. A careful driver may get four to five thousand miles out of his valves with one grinding, while another may only get one or two thousand miles with the selfsame car and engine. There are many factors which enter into the life of a valve seat, and, in the frequency of grinding, all of them have to be taken into account. Some of these are: imperfect cooling of the seats; too strong springs, which cause hammering and thus wear out the seats prematurely; over-lubricating, which causes spitting and sooting, both of which reduce the active life of the valve seat.

Other causes are contributory negligence on the part of the driver in not examining them more often, which results in the failure to discover something in the way of soot or dust caught in between the valve and seat, which is being gradually pressed into the latter. Professional drivers grind valves as soon as a certain distance has been coverd, this being predetermined by experience with a single or many cars.

As far as the grinding action itself is concerned, that, too, is very simple. The tools needed are few and easy to obtain, consisting of a screw-driver and some emery, the latter the finest you can obtain. This should be mixed to a paste with oil, preferably a light cylinder oil. Now, have the valve free of its spring, clean the seat off, and spread a very little of the paste over it. Put the valve into place on top of the paste, and with the screw-driver or brace and screw-driver bit, as shown in Fig. 40, turn the valve on its seat about half a turn, then reverse, and turn back half a turn. All the time, pressure must be exerted upon the valve, so that the emery will take hold and cut. Then move the valve around to a fresh position, and repeat the alternate forward and back motions. The first and second positions will have covered the whole circuit, if just a half turn be used each time. In that case, the third move should be such as to grind on a space not wholly covered by the previous work.

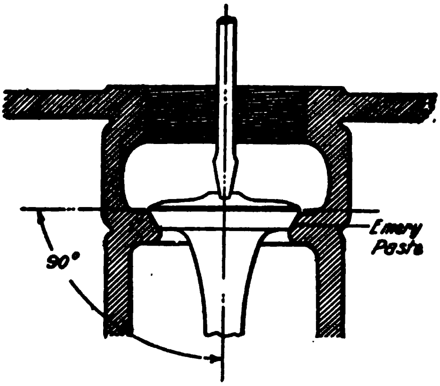


Fig. 40. Grinding Valve Seat.

Beyond this, the only really important point is to have the axis of the valve perfectly square with the seat. If the valve guide has become worn, there is danger of tilting the valve to one side during the grinding process. Then, when in use, it tilts back to the other side and the work of grinding has become useless. There is some danger of grinding off too much. To determine when you have ground enough, note when the pitting has disappeared. After that, grind very little longer before you test the set. This is done by coating the freshly ground seat with a thin film of red lead, or by smoking it with the flame of a candle. Having thus marked it, set the valve lightly into place and rotate. If you have ground to a proper seat, this rotation will scrape off the lead or carbon used in continuous ring. It does not matter how wide this ring is, but it must be continuous.

Taking Out a Valve. On some engines the job of taking out a valve or valves is not as simple as it sounds. On an overhead engine, or an engine with overhead valves, it is not as hard work as on an engine with the valves in pockets in the side of the cylinder, for the overhead valves usually are set into removable seats. The latter come out by simply taking off a yoke or at most, a pair of nuts, and then the cage and with it the valve lifts right out, spring and all. This latter is mentioned because with the ordinary ell or tee head motor, it is the spring which causes all of the trouble. Fig. 41 shows the process of removing the cage and valve from an engine with overhead valves—this is the Truscott engine made for the Truscott boats. To remove these, the valve tappet is held out of the way, and the cage unscrewed. Nothing could be simpler.

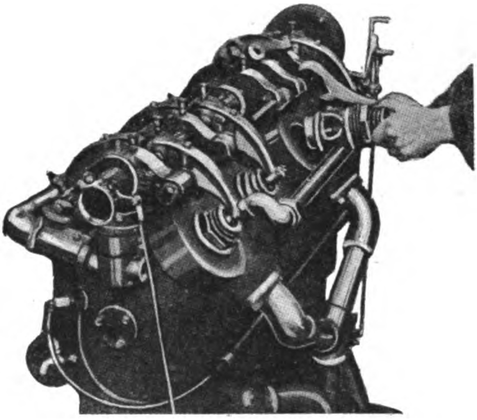


Fig. 41. Removing Valves from a Truscott Marine Engine.

Carbon Deposits. Cleaning an engine of carbon represents a very dirty job, one that is shirked as much as possible. The novice should learn the cause of formation of carbon deposits in the cylinders, and by avoiding this, get out of doing this dirty work. In addition, credit will attach to him for a better running engine. Carbon deposits are formed by the partial combustion of the excess of fuel or lubricating oil. To run with too little oil sounds like bad advice, but it will cure the sooting trouble, and should be practiced as soon as the driver becomes proficient enough to "monkey" with those things. When the engine misfires and in other ways shows the presence of carbon within the cylinders, the driver should seize the first opportunity to pull it down and clean it thoroughly. It has been said that this carbon could be removed by burning it off while the engine is running by means of kerosene. The kerosene together with the jarring action loosens some of it, but as far as burning it off is concerned, that is impossible, for the carbon is a residue from a burning action. The best way is to use a decarbonizer or else take down the entire motor, scrape it clean, and then paint it with a very thin coat of paraffin. It is said that this will aid very materially in preventing the formation of more carbon.

The most important thing to learn about the formation of carbon is that it is caused by incomplete combustion, which also means fuel going to waste. Hence the motor should be cleaned and then run so as to consume the fuel completely, and thereby prevent the formation of scale in the future. This can be effected by proper care in selecting the oil used for lubricating the cylinders, the method of lubrication, and amount of oil fed in. Also, care must be exercised in the selection and use of the fuel, particularly the latter, as this may, in extreme cases, be such as to deposit particles of carbon in the cylinders. Care in this direction is well invested, however, as any autoist who has ever dismantled his engine for cleaning purposes can testify.

Carbon sometimes collects in the muffler, the effect of which may be illustrated by the following: In case of one automobile, it collected there until there was a large quantity of it, sufficient to obstruct the passage of the heated gases. The immediate effect was to heat up the muffler pipe until it was red-hot. This, in turn, transmitted its heat to the exhaust pipe which became red-hot. Finally this reached the cylinders, and the whole exhausting system beyond the cylinders was red-hot. The owner and driver of the car was at his wit's end to find the trouble, seeking it in the carburetion and ignition systems, of course without result. After working on the trouble unsuccessfully for some weeks, he accidentally hit the muffler a sharp blow. The dirt which fell out surprised him so much by its quantity, that he was induced to take the muffler off and examine it. Finding it very full of carbon, he cleaned it and put it back on the machine and no more trouble with hot pipes was experienced.

Oils. Mention having been made of oils above, it will be well to speak of these briefly. They must be purchased with much care. Once an oil is found which does the work satisfactorily, it should be adhered to consistently. No two oils are exactly alike, and for that reason, no two will do the same work under the same conditions in the same way. So, it is advisable to experiment only until an oil is found which will do the work. Thereafter, stick to that brand. As an instance of the impurities which may be found in oils, acids may be mentioned. These are fatal to delicate and closely machined parts such as ball bearings, cylinder walls, pistons, etc., and consequently they should be watched for.

Pure mineral oils contain little acid, and what they do contain is readily determined. Vegetable and animal oils, on the other hand, all have acid content and under the action of heat this may be liberated.

Testing Oil. A simple home test may be practiced as follows: Secure from a druggist a solution of sodium carbonate in an equal weight of water. Place this in a small glass bottle or vial. To test an oil, take a small quantity of the lubricant, and an equal amount of the sodium solution. Put both in another bottle, agitate thoroughly, and then allow it to stand. If any acid is present, a precipitate will settle to the bottom, the amount of the precipitation being a measure of the amount of acid present.

Another method is to allow the acid, if there is any, to attack some metal. To do this proceed as follows: Soak a piece of cloth or, preferably, wicking in the oil suspected of containing acid. Select a piece of steel at random and polish it to a bright surface. Wrap the steel in the soaked rag or wicking, and place in the sunlight but protect it from wind or weather. Allow it to stand several days, and if there is no sign of etching of the surface, repeat with a freshly soaked rag, being careful to use the same oil as before. After two trials, if no sign of the etching appears, you may take it as free from acid.

As far as the oil is concerned, it may, in its passage around through the lubricating system, gather up much dirt. While the oiling system may contain a filter, it is not wise to depend upon this alone, but the pump should be removed occasionally and cleaned. Its condition will give positive proof of the ability of the brass gauze to remove the silt. On many of the modern cars, the pump is located at the bottom of the rear end of the crank case. In this position, it is removed by taking off a couple of bolts. The shaft, which drives it, is provided with a slip joint which allows of the removal and restoration of the pump, without dismantling the whole motor. Fig. 42 shows how a pump is removed from a crank case for cleaning.

The four nuts have been taken off, after which the driver reaches in and takes hold of the pump firmly. A steady downward pull draws the driving gear out of engagement, after which the other hand is used to steady the further downward movement of the pump. This is done carefully, as the superior hardness of the gear over that of the material composing the case, renders the former liable to scratch or scrape the latter.

Other Lubricants. Although no lubricant other than oil has been mentioned, the novice driver should not think that there is no other worth using. Grease and graphite find many places of superior application on the automobile, and their use should be a matter of study. Graphite, in particular, is and has been somewhat mystifying, for it is hard to explain why it is that such a small quantity of graphite will do as much lubricating work as a vastly greater quantity of other lubricating means, such as grease or oil. This is a fact nevertheless. Graphite has found much favor of recent years as an additional substance to be put into the lubricating oil. When thus used, it renders the surface of steel rotating parts hard and glazed so that they withstand frictional retardation better. More than this, the highly polished surface which graphite imparts in a short time, allows of the use of a lessened amount of oil. These two facts account, in part, for the widespread use of graphite. It is usually mixed with the oil directly in the crank case, or *splash part* of the oiling system, and should never be put into the lubricator. The reason for this is that the graphite seems to clog up not only the pipes leading to the bearings, but the moving parts of the pump as well. An excellent way to use it is to clean out the crank case and then, when putting

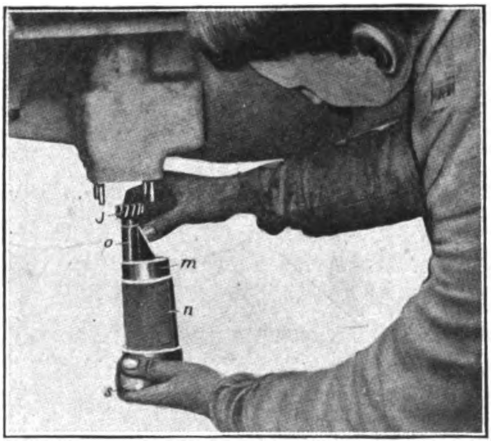


Fig. 42. Removing Oil Pump.

the oil back in or putting in fresh oil, use the graphite-oil mixture. To make this, add a teaspoonful of the purest, finest graphite obtainable to a quart of oil. This sounds like a very small quantity, but it is a fact that only a very small quantity is necessary. After mixing this very thoroughly (take plenty of time to mix it, as it is time well spent) pour it into the case. In actual running the graphite will reach the main bearings, which are the places where it does the most good, as it seems to give them a sort of thin, glazed coating, which acts to protect the pins. A smaller quantity of the oil with graphite in it should be used than of the ordinary clear oil. So, too, if the lubricator or pump is of such a construction that the graphite can be put into it with safety, the feeds can be reduced to about one-half of the amount usually used. That is, the addition of graphite to the oil allows of cutting the oil consumption in half, or, at least, of reducing very materially the amount of oil used.

CARBURETERS

Carbureter derangements form a very large part of the average autoist's troubles, although a very little study of the carbureter will convince anyone that it is a simple rather than a complicated part. Carbureters differ widely from one maker to another, in fact, from one maker's product this year to the same maker's output next year, but in the main, all work on the same principle. There is a fuel supply to a float chamber, the office of the float being to govern the level of the fuel and keep it constant. This it does through the medium of levers, weights, or other parts or combinations of parts, through its connection with the needle valve. The latter allows or prevents the inflow of the fuel, its position determining the amount flowing. From the fuel chamber, there is a connection to the vaporizing chamber, where the gasoline is sprayed into a column of air. The latter picks up the fine particles of the fuel, and vaporizes them. The resulting gas, a mixture of finely divided gasoline particles and air, is conducted into the cylinders by the suction of the pistons. There it is ignited and burns, with resulting expansion, which moves the pistons, and thus, produces power.

If any one of the parts or operations described—the float, float controlling mechanism, needle valve, jet opening, air supply, or suction from the cylinders—be hampered, reduced, or prevented from working, the resulting mixture will vary according to the influence of the deranged or defective part or action upon the result. A rather common trouble is failure to start readily. One puzzled driver described his case as follows:

> The engine starts hard, necessitates priming, and the primer must be held down for a long time. When this is done, it will start and run for a short distance, when it will stop and the same proceeding must be repeated. On taking the carbureter apart, everything was clean and apparently all right.

If you are ever bothered in this way, you may be sure, granting that the spark is good, that the trouble lies in the fuel system. From the description of the trouble, it appears as if conditions were such as to starve the engine, although this was doubtless done unconsciously. This action is due to the fact that the gasoline level has been lowered so far that the suction of the engine does not draw up sufficient fuel for running. The fact that you have to prime to start and then prime to keep a going, even this priming failing to work sometimes, would seem to prove that the engine is not getting enough fuel. The trouble is that the spray nozzle has been raised too high, so that the gasoline level is four or five times as far below the nozzle as it should be. The engine suction must raise the gasoline this distance before any of the fuel will get into the cylinder, and if the distance exceeds the height to which the suction can raise the fuel, none will pass over. In a case of this sort, priming only helps temporarily.

Another somewhat similar trouble, with a not very different remedy is that of the engine ceasing to do its best work or "laying down" under a heavy load such as a stiff hill, deep sand, wet, sticky mud, or similar circumstances in which the maximum power is required. A driver bothered in this way described his trouble thus:

> Whenever I get in a heavy pull and open the throttle wide, the engine back-fires in the carbureter. It never does this on smooth road or when running under ordinary conditions, no matter how much I open the throttle. The trouble seemed to be worse on the magneto than on the batteries. New spark plugs and new batteries helped very little, nor did cleaning the carbureter.

This is apparently carbureter trouble, but the thorough cleaning and adjusting done there would seem to indicate that it is not at fault after all. About the only other solution is that the magneto is slightly out of time, say, to the extent of one tooth, on the driving gear. As the result of this, on slow speeds and even at high speeds with but little load, the effect is not bad enough to be noticed. When working under a heavy load, however, even a slight error in the timing is greatly magnified. The same results might be caused by the valves being incorrectly timed, possibly, by the same small amount, *i. e.*, one tooth out of the way in the meshing of the driving gears. In case making the changes indicated above does not remedy the trouble, look at your inlet valve springs, or at anything else that could possibly cause the inlet to close late or slowly. Look at the valve seats to see if they are in good shape.

Another common trouble is that of wrong location of the jet nozzle, so that the fuel level as fixed by the float does not result in the proper flowing of fuel into the vaporizing chamber. Drivers who have trouble with this are frequently puzzled by it, because they assume that the carbureter is properly adjusted before leaving the factory. This is not always the case. One young driver said:

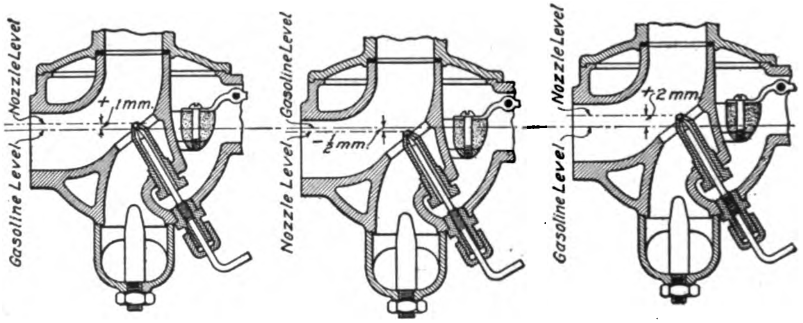


Fig. 43. Section of Carbureter Showing Variations of Nozzle Level. First Figure, Correct; Second, Too Low—Engine Will Flood; Third, Too High—Engine Will Starve.

> What is the cause of this very puzzling knock? My four-cylinder engine develops a bad knock on a hill, which can only be eliminated by retarding the spark, but when that is done, the engine "dies," that is, gives no power. The effect is the same on level roads, when the throttle is opened more than one third. I may have deranged the level of the gasoline within the carbureter, while cleaning it. Would that have this result?

Now, this trouble is directly traceable to the change in the level of the nozzle made when cleaning, and made unconsciously. To quote from a plain statement of the effect of this change:

> By raising the spray nozzle, you lower the level of the gasoline relatively. Therefore, the liquid is less sensitive to the suction, which would reduce

the amount of gasoline used. At low speeds, there would be a tendency to *starve the engine which would be most noticeable on hills.*

The trouble is, that the spray nozzle has been lowered so that the engine does not get enough fuel at slow speeds and on hills. By raising this a small amount, Fig. 43, the engine will be able to suck up more fuel and the trouble ceases with the change. In making this change, be careful not to lower the nozzle too much at once, as the effect then is just as bad, the carbureter flooding at the slightest provocation. The better way is to lower the nozzle a very slight amount, say one-quarter of a millimeter, or perhaps one sixty-fourth inch would not be too much. Try this level out very thoroughly, and when you are satisfied that it is not right, alter the level once more. The experience that you will get during the process will be worth all the time taken up in the series of successive adjustments.

Taking the carbureter apart and cleaning it, then, should be done very carefully, until one becomes thoroughly familiar with it and with the influence which movement of the various parts will have. In Fig. 44, a foreign carbureter, partly taken down, shows how the top part of the float chamber should be removed in order not to damage the delicate needle point at the bottom of the float by which the latter governs the fuel supply. The cover should be loosened, and then lifted straight up, until clear of all remaining parts. With the cover off, the float may readily be removed in the same way, the only care being in starting it. As the amount or length of the needle point within the tapered seat is small, the float need be raised but a small amount to clear that. Then, it may be lifted out as one desires, since it usually is made from a half inch to an inch smaller in diameter than the chamber within which it works.

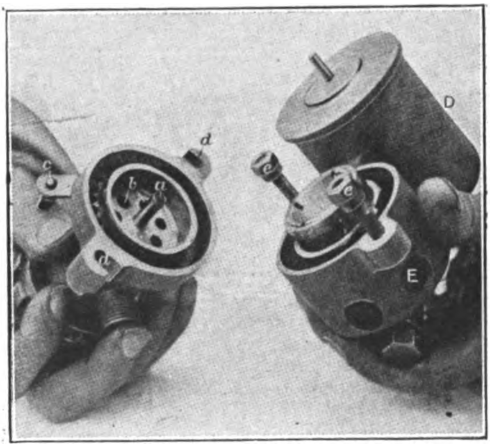


Fig. 44. Method of Dismantling a Carbureter.

The influence of the smallest things may be great as is shown by the following instance, which is illustrated in Fig. 45. A man having a small runabout with a rather large air vent in the gasoline tank, which latter was located directly over the engine, was bothered, in climbing hills, by too rich mixtures. These not only caused the engine to smoke badly, but caused a lack of power. On investigation, he found that the carbureter was located below and nearly underneath the gasoline tank. On a hill, the gasoline flowed out of the air vent, down the side of the tank, and dropped into the air intake thus increasing the mixture. Obviously the cure for this was to change the air intake so that the overflow from the tank could not drop into it, or any part of the carbureter. The sketch, Fig. 45, shows how he was advised to change it; the comment on the trouble and the proposed change were as follows:

The addition of fuel, as you describe, to the air at the air inlet will seriously disturb the running of the engine and probably give so rich a mixture as to choke the engine. It is advisable to remedy this at once, and the best way to do this is to prolong the present air inlet upwards and outwards away from the gasoline tank which causes the trouble. To do this, have a sort of stove pipe made of galvanized iron, tin, or any similar metal. It should be long enough so that its top is as high as the top of the offending tank, then make a big, easy bend away from the latter. The opening or mouth of the pipe should be so formed as to take a screen, which is necessary to keep out the dust, and should preferably be made removable, so that when the screen clogs with dust it can be taken off, cleaned, and replaced. For this purpose use a very fine brass gauze, which can be obtained at any hardware store, and for a small cost.

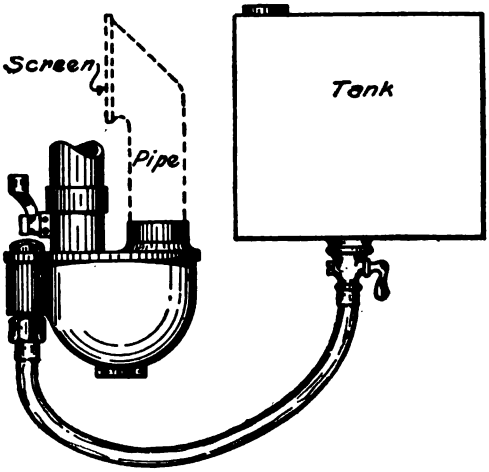


Fig. 45. Puzzling Carbureter Problem Solved.

IGNITION TROUBLES

There are a number of vexatious things to make the novice and prospective driver peevish. Chief among these is the trouble known as *misfiring.* This may be described as a failure of the mixture to fire in any one cylinder. It is usually due to ignition, so that the term as used, now means a failure to fire a charge due to an electrical cause. However, there are many common misfires which are due equally as much to a failure in the fuel supply system, so that the latter meaning attached to the word is somewhat of a misnomer.

Among the causes which contribute to misfiring may be mentioned ignition troubles, such as short-circuit in wires, exhausted battery, pitted or improperly adjusted vibrators of the coil, sooty or cracked plugs, loose connections or switch, dirty timer or commutator, punctured condenser, moisture in coil, wet wires or cables, water on distributing plate, dirt or wear on contacts in distributor, or dirt or wear in timer.

Then, there are the misfires due in part or wholly to the fuel or carburetion system. These may be grouped or listed as follows:

Carburetion and Fuel. Faulty mixture, sediment or water in the carbureter, clogged gasoline strainer, leaky float, clogged spraying nozzle, bent float-valve spindle, stale gasoline, partial stoppage of fuel supply pipe, hole or obstruction in intake pipe or manifold—these are not all the things that might happen, but are the principal ones which the writer's experience has suggested as most likely to occur to cars in general.

Foremost among the several difficulties which may be called *common* misfires, is the lack of a proper mixture. A rich mixture containing a relatively large proportion of gasoline in proportion to air is never desirable, inasmuch as it deposits considerable soot upon the piston, cylinder walls, and valves, and is, moreover, a waste of fuel. The motor will seldom run well on a very rich mixture, and the carbureter should be so adjusted that no more gasoline is fed to the mixing chamber than is sufficient for the motor to develop its full power. The exact mixture may be found by experiment.

A very rich mixture will cause misfiring; the motor will have a tendency to choke at other than high speeds, and is likely to overheat.

A lean or too thin mixture will, on the other hand, lower the efficiency of the motor, giving it a marked tendency to miss at high speeds, accompanied by a popping sound in the carbureter. In this case the needle valve should be adjusted to admit more gasoline, or if due to an excessive supply of air, the auxiliary air-valve should be adjusted to admit less air.

Bent Float Spindle. A bent float spindle will cause missing in one or more cylinders. The float spindle may become bent or it may become jammed into its seat by too vigorous priming. This may be discovered by unscrewing the cover and lifting out the float. Considerable care should be taken in straightening out a bent spindle, and the metal should be placed upon a block of hardwood, another block interposed, and the spindle gently tapped with a hammer.

Leaky Float. A leaking metal float or a fuel-logged cork will cause missing owing to its uncertain and erratic action. A cork float should be thoroughly dried out and then given a couple of coats of shellac to prevent it from absorbing the gasoline. As a new float is not at all expensive, the driver will probably find it more convenient to put in a new one. A metal float must be soldered when it leaks, and as the copper is thin and easily damaged, only a very little solder need be used. Precaution should be taken to keep the hot soldering bit away from the metal.

A clogged gasoline strainer is often the cause of trouble, and this is about the first thing that the autoist should examine when the misfiring is apparently in the fuel supply system. The brass gauze strainer should be frequently taken out and cleaned of any dirt that may have been filtered out of the gasoline.

Obstructed Spraying Nozzle. Owing to the small needle-like opening in the spraying jet, it is not uncommon for a particle of grit to lodge in the orifice and partially stop the flow of gasoline. The obstruction will not always interfere with starting, but as soon as the motor speeds up, the amount of gasoline sucked through the nozzle will not be sufficient for the motor at higher speeds, and it will soon begin to misfire until the motor slows down to first speed. A leak in the intake manifold will cause misfiring in one or two cylinders, and is often mistaken for ignition trouble. The cause may be due to loosening up of the bolts securing the flange to the cylinder.

Inlet Valve. The inlet valve is often the seat of the trouble, and missing here is generally caused by a weak or broken spring, a bent stem, or a carbonized valve. If the valve spring has lost its temper and broken down, the tension will be insufficient to properly hold the valve on its seat and the gas will partially escape and so cause missing. The insertion of an iron washer or two will increase the tension of the defective spring and serve as a temporary road repair. A broken spring may be similarly repaired by placing a washer between the broken ends. A bent valve stem should be taken out and carefully straightened by laying it upon a billet of wood with another block interposed between it and the hammer. Only a very little force is needed, and the stem should be repeatedly tried until it slides freely in its guide.

As was stated before, however, electrical troubles cause the greater part of misfires, and a simple explanation of the more common troubles of this kind will be of much service.

Troublesome Short Circuits. Either a partial or a considerable leakage of the electrical current may be due to worn or frayed insulation, and the bare wire may possibly come in contact with some metal part, and so form a short-circuit to the ground. This may or may not prove a constant short-circuit, as it sometimes happens that the vibration of the car will cause the bare wire to shift about, and the "short" will occur only now and then, as the wire brushes against the metal at intervals. Trouble of this kind is generally due to poor and old-time connections, and will but seldom occur with modern terminals. Perhaps the easiest and best way of correcting this trouble is to wrap a little tape around both the ends of the damaged cable and its binding post, which will keep the loose ends together and at the same time make certain of a good contact at the post.

Failures of the spark plugs due to defects in material and manufacture are not so common nowadays as in the past, but modern plugs are by no means immune from trouble. It is well to test the plugs if trouble is suspected. To do this it should be first ascertained which of the cylinders is misfiring by holding down all the vibrators of the coil but the one to be tested. This is inconvenient without assistance, but the vibrators may be cut out of action by simply inserting a bit of stout paper between the platinum contacts. When the missing cylinder is found, unscrew and examine its plug.

and if the points are clean and everything looks all right, connect up the high-tension wire, lay the plug on the cylinder, and turn the motor over until the proper contact is made. In case no spark is forthcoming and the plug is clean and to all appearances in good condition, it is very probable that the porcelain has developed a crack sufficient to form a leak and cause a troublesome and elusive "short."

However, this method of testing a plug is not infallible, since a minute crack in the insulation—not always visible to the eye—may not interfere with the production of a good spark in the air, but will cause leakage and so make a weak spark, or none at all, when called upon to overcome the greater resistance of the compressed gas. The electric current will always follow the path of least resistance, and as it is called upon to overcome considerable resistance in jumping between the two electrodes of the plug, it is obvious that a comparatively small defect in the insulation will prevent the production of a fat spark at the points.

Broken and Wet Wires. Broken and wet wires are occasionally the source of misfiring, and although little trouble may be anticipated from the well-made modern cables, the wiring of older cars—so largely seen in second-hand shops—is frequently defective. Where the wiring bears unmistakable evidence of having seen better days, the only satisfactory remedy is to put in new wiring throughout the car.

Wet wires are likewise the cause of considerable trouble in the older cars, as in many instances the high-tension cables are carried underneath the flooring and, being unprotected, are likely to get short-circuited through the water and mud splashed up by the wheels. In cases of this kind, it is desirable to re-wire the entire system when possible. In some cars, where this is not convenient, an old length of rubber hose may be pressed into service to enclose and partly protect the otherwise completely exposed wires.

Frequently, it is thought necessary to remove the magneto for examination or adjustment. This was formerly considered quite a task, but with the modern method of mounting, it is very readily effected. As Fig. 46 shows, most magnetos are now strap-held. To remove, then, it is only necessary to loosen the bolt or nut which holds the end of the strap, lift the latter off, and remove the magneto. This assumes that the various wire leads to the switch, cylinders, etc., have been first removed. In the figure, the nut has been removed, and the strap is being pulled aside. The other hand which is grasping the top of the magneto is then just ready to lift it out, as soon as the strap is out of the way.

Worn and Pitted Contact Points. The platinum contact points of the tremblers of the coil, if not properly attended to, will become rough and jagged and the poor contact will result in misfiring. The points should be examined occasionally, and, if uneven, they should be trimmed flat with a fine jeweler's or manicurist's file. The adjustment of the vibrator screw also plays an important part, and should be given its share of attention. A stiff tension is never necessary or desirable, as it will not only consume a greater amount of current, but will result in rapid wear and pitting of the contacts. The trembler should be adjusted with only sufficient tension to cause it to vibrate at a moderately high-pitched buzz. This adjustment by ear rests altogether with the experience and judgment of the driver, which may or may not be good.

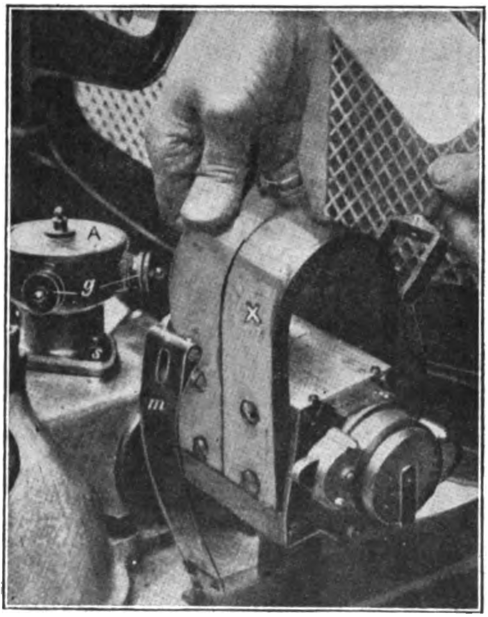


Fig. 46. Removing Magnets.

When the unit coil system is used—and this arrangement is now in general use—it is important, for the best coil service, that the vibrators of the several units be tuned as near alike as possible. This may be closely approximated by sound, but the only sure method is to measure the consumption of the current by means of a special ammeter. The exact amperage varies somewhat in different coils from ½ to ¾ amperes—and to obtain maximum efficiency the maker's directions should be followed.

Exhausted Battery. A rundown battery is a very common source of misfiring, and although the symptoms are plainly apparent in troubles of this kind, the difficulty is not always traced to the proper cause. The fact that a weak battery will not generally prevent starting and only causes a misfire after the car is well under way, is, no doubt, the reason why the real trouble is not at once suspected. And again, the motor may run fairly well at medium speeds, but when the throttle is opened to admit more gas, the spark is too weak to fire the heavier charge and the motor commences to misfire, finally coming to a stop. In fact, when the battery fails to respond to the spark advance lever it may be taken as pretty good evidence that the voltage is too low, and that a new set of dry cells should be connected up, or the battery re-charged if of the accumulator type.

If the two sets of dry cells are used, they may be made to give some little additional service by connecting up in series—carbon to zinc. If two storage cells furnish the ignition current, connect them up in parallel—carbon to carbon and zinc to zinc. To avoid the annoyance of a weak battery, each dry cell should be occasionally tested for amperage and the defective cell renewed. A storage cell should be charged regularly once a month, and should never be allowed to become discharged.

Switches occasionally work loose, and, while an uncommon source of misfiring, it will occur now and then. A loose switch generally provides such poor contact that the motor will stop completely, but it may also cause missing in but one or two of the four cylinders.

The timer or commutator should be washed out thoroughly with gasoline at least once a week, to remove dust or other substances which will likely interfere with a perfect contact. If neglected, and dust and oil allowed to accumulate, the contacts will be imperfectly made and, the current being poorly distributed, misfiring will ensue.

Condenser and Short-Circuit in Coil. The condenser is not likely to cause trouble, and the most serious injury likely to befall this important part of the system is a puncture caused by the use of a battery generating a higher pressure (voltage) than the coil will stand. In this case the coil must be sent to the makers for repair. It occasionally happens, however, that misfiring results from a broken connection to the condenser, or is due to the presence of dust or oil on the spring contacts. If trouble is suspected in the condenser, the contacts should be examined and cleaned with a bit of cloth wet with gasoline.

Water or Moisture in the Coil. Water or moisture in the coil will form a short-circuit and produce missing in the cylinder, and will rapidly exhaust the battery current. A primary or single wound coil—such as is used in low-tension make-and-break ignition—may be dried out, but the only way to fix up the high-tension coil is to send it to the manufacturers.

Magneto. In addition to those misfiring troubles which have just been mentioned, many of which are common to both magneto and battery systems, there are a few misfiring troubles which are confined to the magneto itself. Perhaps one of the most common causes of magneto misfiring is due to the interrupter-contact-arm roller becoming worn. A fiber roller will often wear unevenly, causing the cam to slip over the worn flat spot without making a good contact. In case of steel rollers and fiber cams, the latter will sooner or later show signs of wear.

Miscellaneous Troubles. The contact interrupter spring is also a common source of missing, as the spring loses its elasticity and becomes weak through constant use. Loose interrupter contacts are not quite so common, but will occasionally cause misfiring by working loose and so provide insufficient surface to insure a good contact.

Armature bearings work loose in course of time and cause misfiring by making too short a contact. Dust on the insulated face of the distributor is likewise conducive to missing, and the autoist should make it a point to keep this surface clean.

MEASURING INSTRUMENTS

A point worth more than passing mention is, that all ignition troubles may be detected at once by the use of common electrical measuring instruments. The two ordinary instruments are the *voltmeter* and the *ammeter*. The former measures the voltage or the pressure of the current, while the latter indicates the rate of flow or amperage of the current. Since both are necessary, they are combined in the modern instrument into a single unit, Fig. 47. When mounted upon the dash board of the car, it is connected up as shown in the wiring diagram, Fig. 48. With this instrument in position and connected up, one may make a simple test at the slightest sign of trouble, and find out at once the source. Moreover, aside from making a test of this sort at will, it is possible to tabulate the common electrical troubles, their indications on the instruments, and their remedies. This makes a glance at the instruments, and another at the table, sufficient to start a person on the process correcting the trouble.

How to Proceed with the Test. In proceeding to make tests with the volt-ammeter, after having connected it up as indicated, the first thing to do is to make the distance between the spark-plug points as nearly uniform as possible, so that the width of the gap shall not exceed $\frac{8}{100}$ inch and then file the platinum points of the vibrators and contact screws so as to be sure that they are perfectly flat and true as well as smooth.

For this operation, a Nicholson XF Swiss file, about number 6 cut, should be used, because the ordinary fine-cut file is too coarse and cuts away too much metal. After filing the points, the contact screws of each unit should be screwed down until the vibrator has a play of about $\frac{1}{16}$ of an inch between the screw and the iron core.

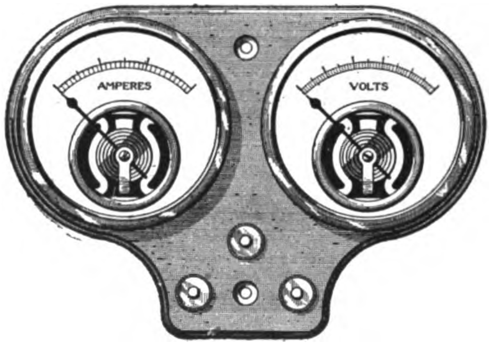


Fig. 47. Hoyt Volt-Ammeter.

Then, with the gasoline supply to the carbureter shut off and compression relief cocks open, turn the engine over until the timer makes contact and sparking takes place in one of the cylinders, any one being equally good.

Note the reading of the ammeter when the timer closes the primary circuit, and if the current consumption of the coil is greater than $\frac{8}{10}$ ampere, increase the vibrator gap by unscrewing the contact screw, and thus decrease the flow of current. Should the vibrator fail to act, however, screw down the contact screw and thus decrease the gap until the vibrator is brought into action. Proceed in the same manner to adjust each of the vibrators until the current consumption of the coil units is equal throughout their number.

In making adjustments while the engine is at rest, the circuit being closed by the timer for a considerably longer interval of time than when in actual operation, it is necessary to set them for a current consumption about twice as great as is desired, because in actual operation the flow of current through the coils is intermittent, and the ammeter needle will stand at a point representing the mean current flow. For example, a two-unit coil adjusted to take ¾ ampere would show from ⅜ to ½ ampere on the ammeter, depending on whether the period of make or period of break is the longer.

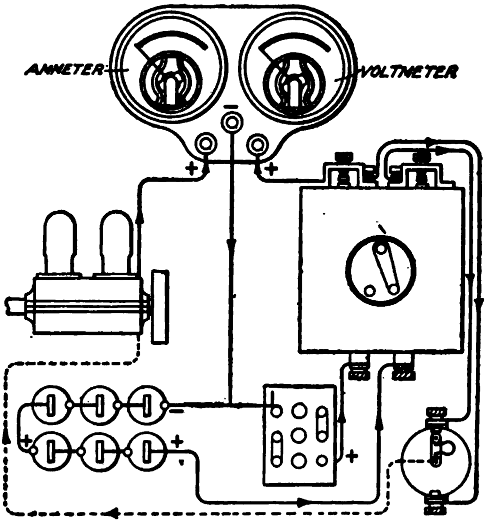


Fig. 48. Wiring Diagram for Volt-Ammeter Circuit.

Effect of Construction on Consumption. Since the construction of a coil affects the current consumption, and wide variations in the sparking efficiency of different makes arise from differences in usage as well as construction, no definite rules can be given for the exact point at which a coil vibrator should give best results. Generally speaking, however, it may be said that a coil adjusted to operate on less than $\frac{1}{10}$ ampere will give a thin, weak spark which would only fire a rich mixture. When adjusted to take more than $\frac{8}{10}$ ampere, trouble will be experienced from pitting and sticking of the platinum contact points and from rapid deterioration of the battery.

With the volt-ammeter in circuit, an observation of the normal rate of deterioration, after adjustments have been made, enables the operator to ascertain the relation between mileage and battery consumption. For instance, if a car will run 300 miles when the current consumption is such as to cause a pressure loss of ½ volt, then the car will run another 300 miles with a like drop in voltage, whether the battery is of the primary dry-cell or of the secondary storage type. Hence, a glance at the voltmeter will enable the operator to judge what mileage can be obtained from the battery before it is exhausted.

Whatever may be the cause of a change that affects the battery circuit, the voltmeter gives instantaneous indication thereof, the needle or pointer remaining steady only so long as conditions are normal. With a loose contact, the needle would oscillate back and forth; with a broken wire it would not move from zero; with a poor contact due to a corroded terminal, the reading would be lower than normal; and in case one or more cells should become short-circuited, the needle would drop to an extent depending on the scale value of the cells cut out. If the pointer does not remain steady on that point of the scale representing the voltage while the car is in operation, look for the trouble at once and remedy it.

What the Ammeter Reading Signifies. The operator having also familiarized himself with the significance of the ammeter indications, a glance at it shows whether there is a normal flow of current through the coil. Any departure from normal conditions, in fact, any change in the circuit that causes a variation in the quantity or volume of current flowing through the coil, is shown and can be accounted for by the behavior of the ammeter, whose indications serve as a reliable guide in locating ignition troubles. Poor contact is shown in a diminished current flow; too small a gap between the vibrator or spark points is indicated by an abnormally high reading; and a short circuit at the spark plug, due to soot or breakage, will cause the needle to be thrown to the extreme point of its movement. A loose connection causes oscillation, while a broken wire is indicated by stoppage of the engine and zero reading of the ammeter. A study of Table II will give some idea of the extent to which the volt-ammeter can be made of service in detecting ignition troubles.

SPRING REPAIRS

Due to the fact that spring makers the country over are now using better materials than before, spring breakages are few and far between. Time was when this was decidedly different, and a knowledge of spring repairs was very valuable, and even now, such knowledge is worth having. The usual spring breakage is a shearing off action

TABLE II

Common Ignition Troubles and Remedies

Reading of Voltmeter	Corresponding Ammeter Reading	Cause	Remedy
Steady.....	Regular .	Normal conditions........	None necessary
Oscillating needle	Irregular	Loose contact in battery circuit—Leakage of secondary current — Short circuit or exhausted cells	Tighten connections—See that timer contact is made evenly—Eliminate leakage
Uniform or gradual drop	Regular.	Normal deterioration of battery	None required
Abnormal drop	High....	Rapid deterioration of battery because of short circuit at plug or in battery box—Improper adjustment of coil-vibrator or spark, plug gaps, latter being too narrow—One or two exhausted cells	Eliminate short circuit —Readjust vibrator and spark gaps—Replace exhausted cells
Normal....	Low....	Poor contact in timer, vibrator, or connections—Short circuiting of cells	Clean contacts, eliminating effects of corrosion or wear
Normal....	High....	Sooted spark plug—Gaps at vibrator or spark plug too small—Decreased coil efficiency	Clean spark plugs—Increase width of gaps —Readjust tension of vibrator spring
Normal....	Irregular	Poor timer contact........	Fix timer
Normal....	Zero....	Broken ground wire.......	Put in new wire
Zero.......	Zero....	Broken wire between coil and battery or broken battery connections	Put in new wire

of the upper leaf. When this occurs, and the lower leaves are found to be still intact, it is possible to make a good serviceable repair with any stiff hard substance at hand, which may be fastened readily to the upper part of the spring. For fastening, the car may be raised with a jack, so as to take all weight off of the spring. Then, rope, wire, or any similar material may be bound around the two so as to fasten the broken spring firmly to the temporary stiffener. The weight may then be lowered onto it gradually. By proceeding cautiously, it is possible to get home with a repair of this sort, even when the repair part is but a piece of wood. This form of breakage and repair was so common at one time, and that not so very long ago, that steel strips were made and sold for this particular purpose. In the illustration, Fig. 49, one of the steel bars *A* is shown, as well as its application to broken springs in several positions—*B* shows it applied to a spring broken in the center; *C* is a view of its application to one broken at the end, or at least, farther out than the preceding one; *D* shows its application to a spring with the whole end of the upper leaf broken off. In this position, the steel bar is bolted up the same as in the other cases, except that the end is allowed to project so that the drilled hole will come in a position corresponding to the former spring eye.

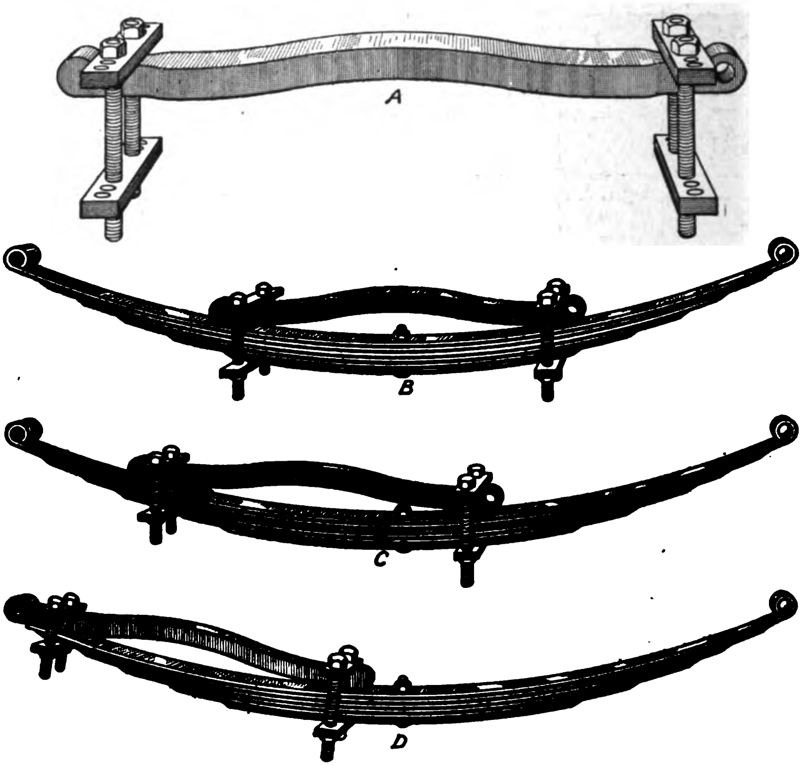


Fig. 49. Steel Bar Carried for Spring Repairs.

DEMOUNTABLE RIMS

Tire changing used to be the "bugaboo" of the lazy driver; but now, all that has been changed by the advent of the demountable rim, the demountable wheel, the quick change rim, and similar

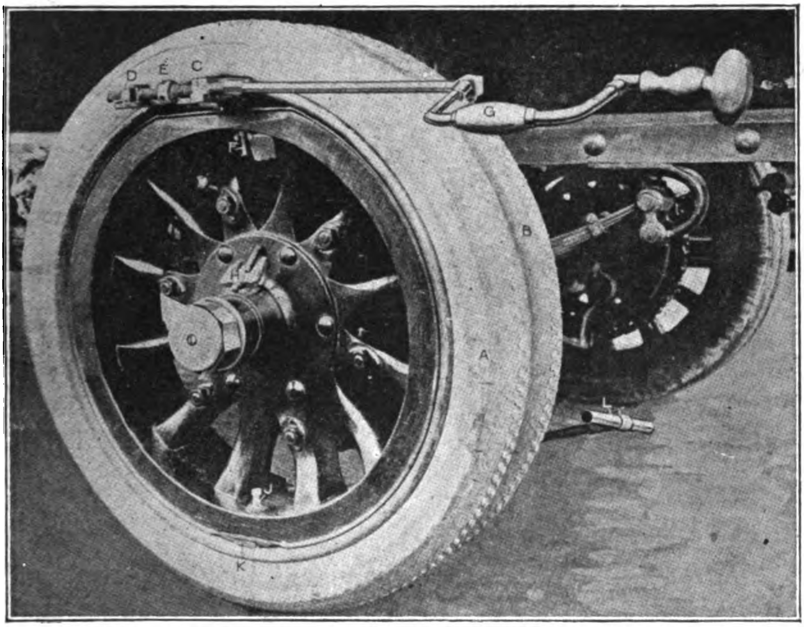


Fig. 50. Michelin Tires Showing Demounting Mechanism.

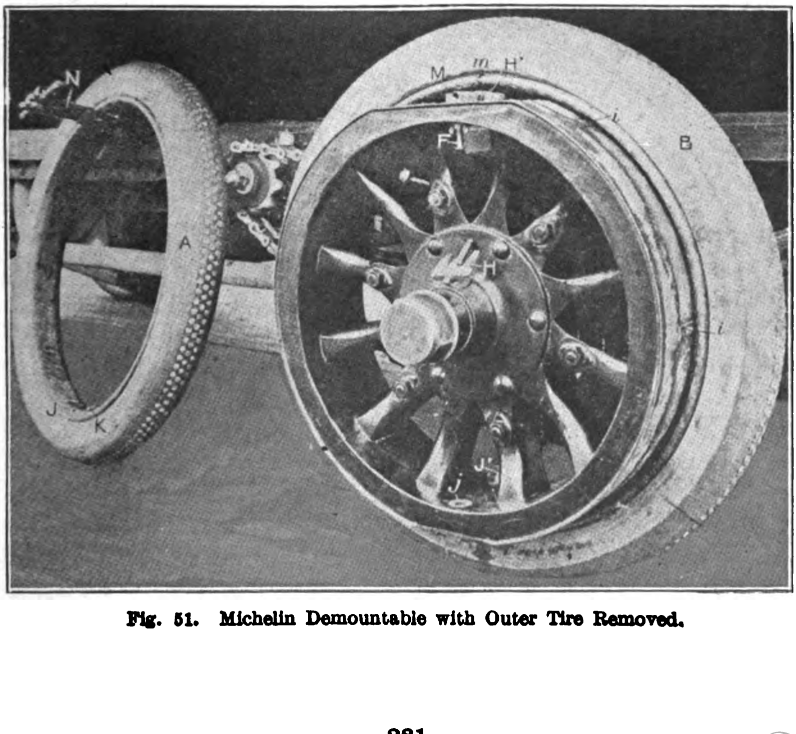


Fig. 51. Michelin Demountable with Outer Tire Removed.

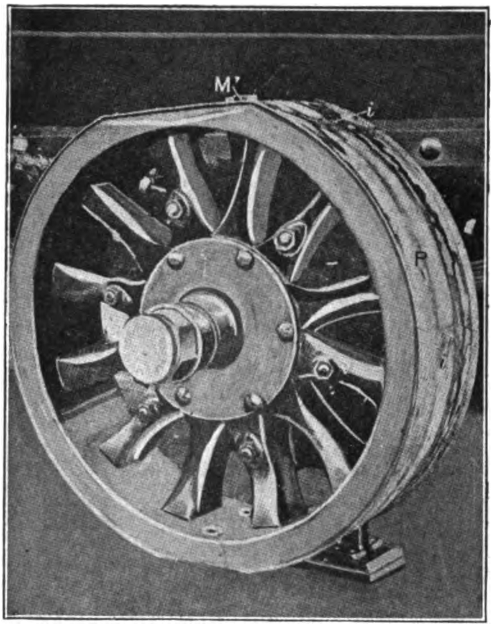


Fig. 52. Bus Wheel with Both Tires Removed.

devices. All of these administer to the comfort of the driver, in that they substitute for the spare shoe or external part of the tire formerly carried, another wheel or rim with a fully inflated tire all ready for use. The change, then, in case of a puncture or blowout, is a change of rims or wheels instead of shoes. The damaged tire is then carried home and repaired at leisure.

The designs of demountable rims are many and various, so much so that space prevents illustrating or describing half of them. The subject is so important, however, that a few selected at random will be described and illustrated. Thus, for track racing, where even *seconds* are precious, the Michelin Company has developed the demountable rim shown in Fig. 50, Fig. 51, and Fig. 52. The first shows the wheel in position, with tire in place, and the special bit and brace developed for doing the work of changing, also in place. A few quick turns of this, made in less time than it takes to tell it, and the tire is free to be taken off, sideways, as soon as the brace is taken out of the way. The illustration shows it in use on a bus fitted with double tires, and in Fig. 51, the outer tire has been removed. In Fig. 52, both tires

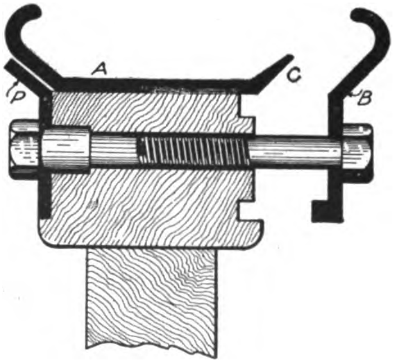


Fig. 53. Eclair Demountable Rim.

have been removed, and the wheel stands free and clear, showing its construction.

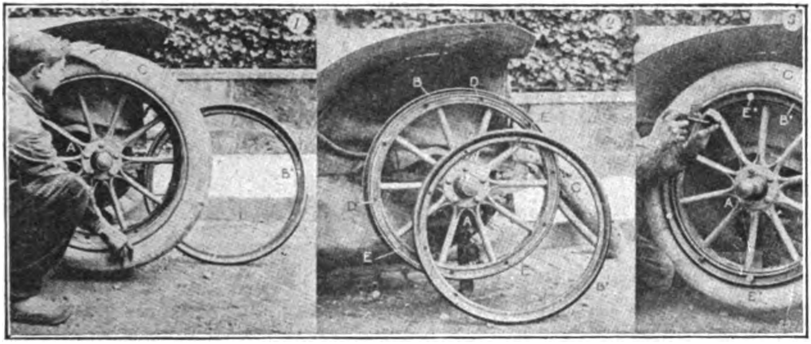


Fig. 54. Operations in Mounting an Eclair Rim.

In the wheel, or rather rim, Eclair, another French product, a special rim shape has been developed for this purpose and, in fact, this has been done with nearly all demountable rims. The shape in this case, as shown in the illustration, Fig. 53, is that of the ordinary clincher rim cut into two pieces, with a prolonged flange added to one of them in a vertical plane. This is for the purpose of holding the tire down to the rim, as it will be observed that the fixed part of the rim does not do so, except from its circular shape. The bolts are used to fasten the clamping rim on and to keep it from rotating. The left-hand part of the rim, marked *A*, carries the tire, and when the old tire and rim have been removed,

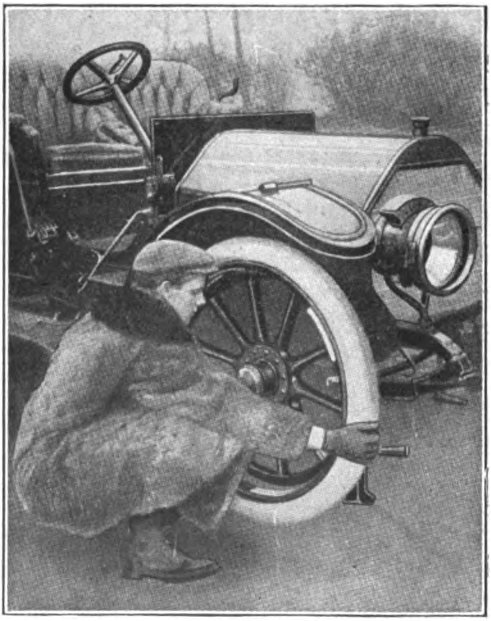


Fig. 55 A Dow Demountable—Loosening the Rim.

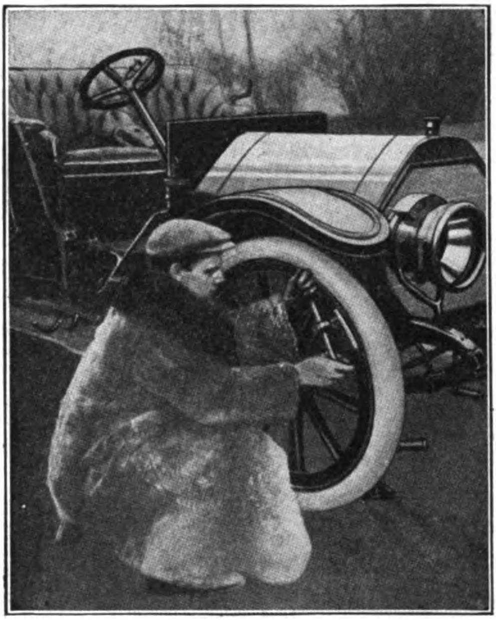


Fig. 56. A Dow Demountable—Removing the Tire.

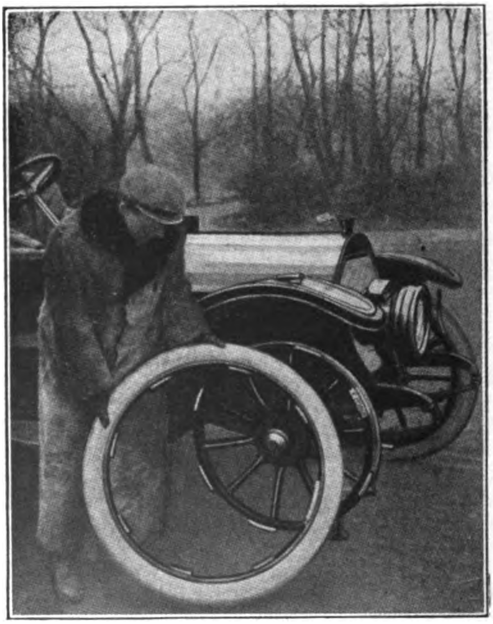


Fig. 57. A Dow Demountable—Rim Removed.

this, carrying a fully inflated new tire, is slipped into place. Then the locking rim *B* is slipped on, and through the medium of the bolts, ten in number, is pulled up tight, locking the first rim with the tire, tightly in place. The first picture, Fig. 54, shows a man slipping on the first part *A* with the tire, while beside the wheel is seen the locking ring *B*. In the last picture, he is shown tightening up the bolts with a special wrench for this purpose. The bit and brace are also used. In the central picture are to be seen all of the components. Special attention is called to a feature which would otherwise be missed. This is the rubber ring *D*, which is used to insure tightness, and an even pressure all around; it is placed next to the tire, and within the locking ring.

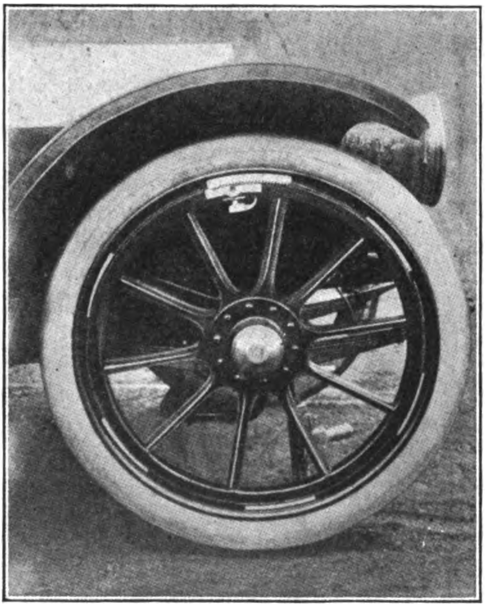


Fig. 58. A Dow Demountable Completely in Place.

In respect to demountable rims, the American does not have to admit any foreign superiority, for American demountables are just as good as those from the other side. One very good demountable rim is the Dow, made by the Dow Rim Company, New York City. This form utilizes the wedge as the basis of its locking device. The wheel felly carries on its outer circumference seven bronze plates which taper both laterally and circumferentially. The rim carries a similar set of plates of the same number and similarly placed. It also carries a rack, while the wheel carries a plate with a hole in it. A special tool for this wheel consists of a central axis with a small gear mounted upon it, and a cross bar to form a handle. When the end of this tool is placed in the hole in the felly, the gear will engage with the rack on the rim. Then by rotating the tool, the rim and with it the tire, are also rotated upon the felly. This rotation in one direction tightens the rim on the felly and in the other direction loosens it, according as the wedges are forced up to one another or apart. The illustration, Fig. 55, shows the wheel jacked up off of the ground, and the driver just starting work upon it. A turn of the special wrench, and the wedges are freed. Then, as Fig. 56 illustrates, the driver grasps the tire firmly with both hands and pulls it outward and off. Fig. 57 pictures the rim and damaged tire completely removed; or it may be taken to represent the new tire which will be put back into the place of the damaged one. In that case, the operations are reversed, the wheel is slid into place, the wrench is applied, rim rotated until wedges lock, and the change has been completed in twenty seconds, leaving the wheel as it appears in Fig. 58.

SKIDDING

Not very long ago side slipping and skidding were supposed to be much the same thing, some people holding skidding to be a form of side slipping, and *vice versa.* Today, with a greater knowledge of both it appears that the two are entirely different as to causes, effects, and methods of prevention. Side slipping, which is much more simple and of considerably less importance, will be treated first.

Side Slipping. A car might exert sufficient traction over glossy ice to run very well as long as a straightforward path was followed, but as soon as a turn was made, the car would "side" in the direction of the former straight path. Of this slipping or sliding action, the rear wheels would do the greater part, the front ones acting as a pivot about which the rear end turned. Similarly in driving along a wet and slippery road surface, if a turn be made quickly, the inertia of motion of the rear end of the car will cause it to slide around the sharp corner. This is side slipping, as it is known in the automobile world.

Again, if the roadbed be narrow, as many country roads are, the wheels—either front or rear—might easily slip off of the crowned portion of the surface down to the side of the road. This might happen either on a road too highly crowned, or on a less highly cambered surface on which a light rain had fallen or which had been recently oiled. This, too, is called side slipping.

Not one of these sources of trouble is dangerous in the sense that it can not be controlled. It is never necessary to drive over slippery ice, and, when driving across wet and exceedingly slippery pavements or roads and around corners, one can always drive slowly and with great caution. The highly crowned or freshly-oiled roads can also always be avoided by traveling on other highways.

Theory of Skidding. The subject of skidding may not be so lightly dismissed for in it there are many things which can not be explained and, therefore, can not be avoided. The danger in skidding is due to the absolute lack of control on the part of the driver, particularly if the car has already started to skid. Where this action may lead a car no one can tell. During this "wild" period the car may run into or be run into by other cars, or may collide with obstacles along the roadside, thereby causing much damage. This almost always occurs upon wet or slippery pavements, and nearly always occurs in attempting to check the speed of the car while crossing such pavements or in attempting to make a sharp turn upon the same without checking the speed.

The actual action of skidding is something like this: The wheels, either front or rear, suddenly and without apparent cause start to swing around, generally taking such a direction as to follow a circle drawn with the other wheels as a center and the length of the wheelbase as a radius. This action is usually continued until a complete half circle has been covered. The traversing of this semicircle need not necessarily conclude the action, for cases are known in which a very violent skid resulted in a continuous uncontrollable swinging around and around, the car making several complete revolutions.

This latter action can best be compared to the motion of a couple dancing in which each revolution is accompanied by a forward motion. In the case of a car executing a very violent skid, the car swings around and around, either the rear wheels swinging with the front ones as a pivot, or the reverse, while at the same time the skidding machine executes a forward motion, generally in the direction in which the car was progressing before the skid started.

Causes of Skidding. *Power vs. Traction.* Skidding is induced or invited, when driving over wet or slippery surfaces: (1) When the clutch is thrown suddenly in or out, the engine being still running;

(2) when, with the power on, the brakes are suddenly applied; (3) when the steering gear is turned too sharply, with the power on and the clutch in. A close analysis of these cases will show that they may be interpreted from a lack of balance between the driving power and the useful force, that is, either the wheels revolve but do not progress or else they progress but do not revolve.

Thus, in the *first* case, if the clutch be out, let us consider the effect of suddenly dropping it in. The driving power of the engine is relatively great, but as the wheels have no traction on the slippery surface, this force can not be applied; there is, therefore, a lack of balance, and skidding occurs because of excess power from the engine.

Consider the alternate case, where the clutch, which is in, is suddenly withdrawn leaving the car moving forward under its own momentum. The engine here is useful, not as a source of power, but merely as a part of the comparatively heavy weight which is moving forward through its own inertia. A skid caused under these circumstances is the result of a lack of engine power, the excess here being on the side of traction, or progress, rather than revolution, as in the first case.

The *second* case, in which the brakes are applied with the engine power on, is seen to be closely analogous to the case of throwing out the clutch. Throwing on the brakes is about the same as cutting off the source of power, for in either case the forward motion is violently retarded. Here again, there is an excess of progress rather than of revolution, of traction instead of propelling power.

The *third* case is different from any of the preceding. With the power on, clutch in, and brakes off, giving the steering wheel a sharp twist in either direction starts a skid. The turning of the sharp angle reduces the traction, which is small at best, to a point at which it is not sufficient to propel the car forward. As the same power is available as heretofore to propel it forward, this is evidently another instance of an excess of power over traction, a superiority of revolution over progress.

It is a curious fact in this connection that slightly flattened or partly deflated tires will cause skidding to occur more easily than well inflated or hard tires. It would be natural to suppose that a slightly flattened tire, having more area of contact than the well inflated tire, would develop more of a drag or grip on the ground,

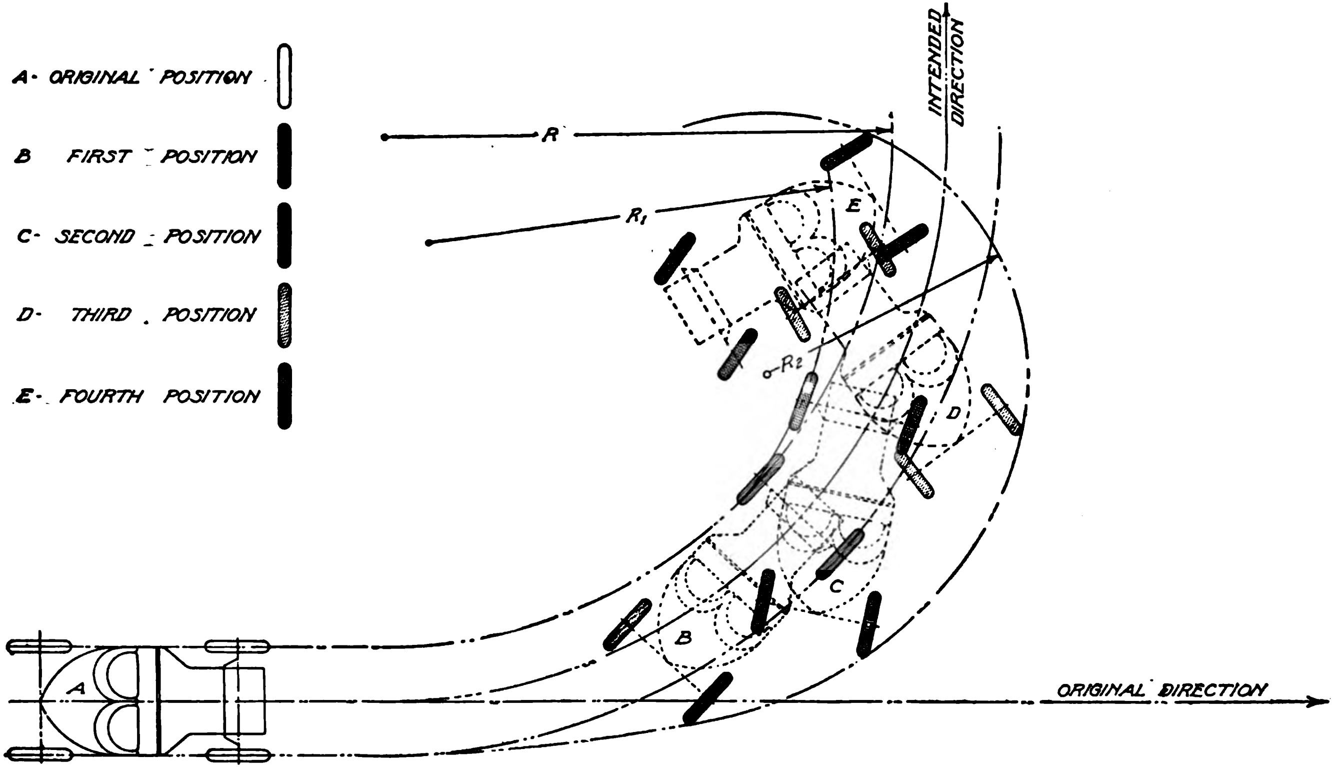


Fig. 59. Diagram Showing the Development of a Skid as a Car Rounds a Curve

thus tending to minimize the skidding action, but such does not appear to be the case.

Considering the case of a car going around a sharp turn, the momentum of the vehicle and the power of the engine combine to urge the car in the former direction, that is, along the tangent to the curve. The position of the front wheels, however, tends to guide the vehicle in a different direction, the engine giving some aid, according to the amount of traction. Should this traction be small, the tangential forces are much the larger and assume control of the situation, the side movement of the rear wheels becoming sufficient to nullify the action of the front wheels in rounding the curve, thus bringing them to a stop, and making them act somewhat as pivots for the rear wheels which continue their motion until the entire force is expended. The performance may be analyzed by the aid of Fig. 59, in which A is the original position of the car, which is about to make a turn of radius R. The car proceeds a short distance around this curve, to such position as B, when the superior impelling force of the rear end causes it to take a different course. This path is a curve whose radius rapidly decreases from the value R to, say, R_2, probably reaching nearly its limiting value which is the length of wheel base of the car. At the same time the front wheels are forced around in the arc of a circle of radius R_1, this being shorter than R but much longer than R_2. This action results in positions C and D. With the rear wheels following a constantly shortening radius while the front wheels are forced around in the arc of a circle which is shortening, it is true, but much more slowly than the circle of the rear wheels, it is obvious that the rear wheels will soon pass the front ones. This is actually shown in position E of the figure. This analysis should give as clear an idea of the process of skidding around a curve as could possibly be obtained from anything except a set of moving pictures, and these would be very difficult to obtain.

Miscellaneous Causes. Some of the causes of skidding have been discussed, but some further explanations may be of service. If the power applied to the rear wheels is not equally divided between the two wheels for any reason, the opportunities for skidding are greatly increased. This may be brought about by a tight bearing in one wheel, or a bearing which, by improper fitting, grips the wheel at one point but is loose at another; or the bearings on the differential may grip one side of the differential case more tightly than the other, thus causing the differential to give more power to one wheel than the other.

Again, the design and construction of brakes may easily affect the behavior of the car. If these are not designed with an equalizer, or if fitted so that the equalizer can not work when the brakes are applied, more snubbing effort will be applied to one wheel than to another.

The loading of the chassis may increase or decrease the chance of skidding, for too heavy a load on the front wheels naturally means too light a weight on the rear end. It is a fact that cars thus constructed, especially when carrying no rear-seat passengers, skid very easily.

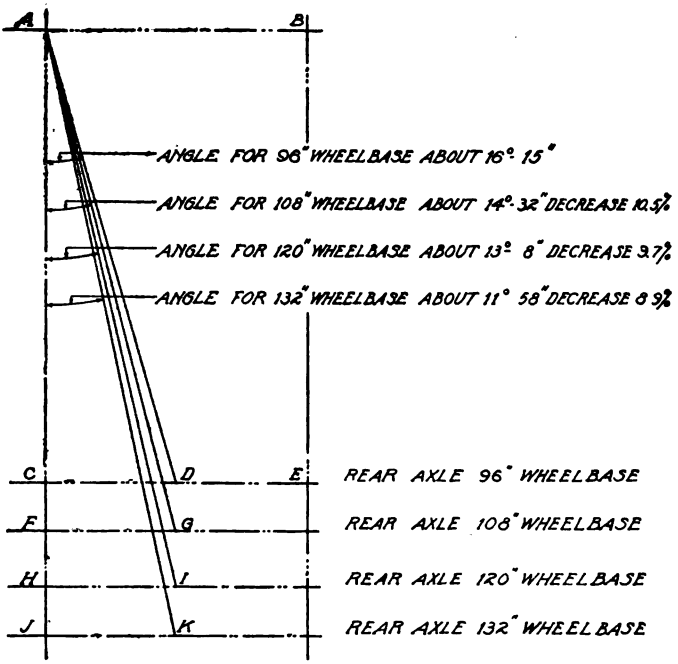

A
B
ANGLE FOR 96" WHEELBASE ABOUT 16° 15"
ANGLE FOR 108" WHEELBASE ABOUT 14°-32" DECREASE 10.5%
ANGLE FOR 120" WHEELBASE ABOUT 13° 8" DECREASE 9.7%
ANGLE FOR 132" WHEELBASE ABOUT 11° 58" DECREASE 8 9%
C
D
E
REAR AXLE 96" WHEELBASE
F
G
REAR AXLE 108" WHEELBASE
H
I
REAR AXLE 120" WHEELBASE
J
K
REAR AXLE 132" WHEELBASE

Fig. 60. Diagram Showing Determination of Skidding Angle for Different Wheel Bases

Methods of Prevention. *Long Wheel Base.* The length of the wheel base has an influence on skidding possibilities which may be analyzed by the aid of Fig. 60. Let *AB* represent the front axle, and *CE* the rear axle of the car. Marking the center *D* of the rear axle and drawing two lines *AC* and *AD*, these two lines form an angle which might be termed the pivotal or skidding angle. When this angle is large, skidding occurs easily and often, and, therefore, anything which tends to reduce this angle, such as lengthening the wheel base, tends to reduce skidding. The distance *AC* represents a wheel base of 8 feet or 96 inches. If this be increased by 1 foot, *i. e.*, to 108 inches, the angle decreases from *CAD* to *FAG*. A simple calculation shows that the first angle is 16° 15′ while the second is 14° 32′, a decrease of 10.5 per cent. If the statement above is true, skidding should be reduced 10 per cent by lengthening the wheel base from 96 to 108 inches.

Similarly, *HI* shows the location of the rear axle for a 120-inch wheel base, causing a further decrease of 9.7 per cent, while *JK* shows the axle position when the wheel base is lengthened to 132 inches, a further decrease of 8.9 per cent. The decrease of the last over the first, amounts to 26.3 per cent.

Diagonal Braking. Diagonal braking, that is, braking one front and the opposite rear wheel, has been advocated as a cure for skidding. The same idea is conveyed in the present agitation of tire manufacturers for those persons who can not afford four new non-skid tread tires, as well as for those who do not believe in their efficacy, to try one on a front wheel and another on a diagonally opposite rear wheel. It is held that this combination gives perfect non-skidding qualities.

Miscellaneous Tire Devices. Non-skid tire treads, tire chains, rope grips, and similar devices are well-known and successful preventives. Practically every one of them works on the principle that since skidding is a side-slipping action, anything which prevents slipping either prevents skidding or reduces it to a minimum. The one fault with non-skid treads is that being rubber they wear smooth on ordinary roads, so that when wet weather comes the rubber-formed devices have worn so smooth as to be practically useless.

Metal devices, other than studded tire treads, must be put on the tires in wet weather, a task which is considered a good deal of bother by most persons; on the other hand, metal-studded tires, although always ready and very effective as skidding preventers, are somewhat noisy at all times. So, one might truthfully say that no perfect anti-skid device has yet been brought out.

Front-Wheel Brakes. Front-wheel brakes are the latest device offered for the purpose of preventing skidding and seem to give more promise than any of the others, being of such a nature as to be available in addition to the other devices. Front-wheel brakes add to the vehicle in other ways, too, and the practice of fitting them in place of, or in addition to, rear wheel brakes is growing rapidly. Beginning in England in 1910, some four or five manufacturers adopted them after more than a year's trial and test. One year ago, this list received important English additions, while at present front brakes are being taken up by one prominent Italian maker, two or three very prominent French manufacturers, and several more from Belgium and other countries.

These brakes are said to be equally as effective against rear or front skidding, although one might think from the location of the brakes that front skidding alone is prevented. The front brakes are applied first as strongly as possible, and then by following this with an application of the rear brakes, the car may be stopped anywhere and in a much shorter space of time than was possible with any former brake equipment. When this fact becomes better understood, front brakes will become universal on the better class of cars, despite the complications which they bring about.

Before going into the details of a number of front brakes, it will be well to call attention to the reason why this form of brake is more effective than the rear brake. In braking at the rear wheels, the greater portion of the load is in front of the wheels upon which the brakes act, resulting in the inertia of the heavy and bulky moving mass, producing a piling-up action on the front wheels. This action is in part responsible for skidding, in that a slight resistance on one side will cause the whole force to be directed to the other, with an ensuing front-wheel skid in that direction.

Now, if the front wheels be braked, the same piling-up action will result, but instead of being detrimental, it is advantageous, for it adds weight and effectiveness to the brakes, making them take hold better and thus stop the car quicker. The greater the weight or the greater the piling-up action the more effective they will become.

Again, the majority if not all of the stresses of skidding as well as of braking (whether skidding occurs or not) are taken by the tires, the rear tires receiving all of this and, in consequence, wearing out much more quickly. Front-wheel brakes equalize this, for while with them the front tires take most of the braking stresses, the rears take all of the driving stresses, and neither one takes any side or skidding strains, thus increasing the life and efficiency of the tires.

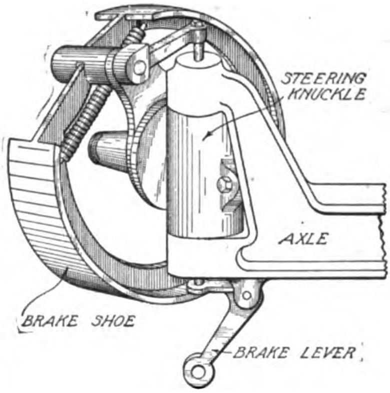


Fig. 61. Spyker Front-Wheel Brake-

The one difficulty in the way of the universal adoption of front-wheel brakes, despite their prevention of skidding, is that the brake must turn with the wheel about the steering pivot or steering knuckle pin, and still be as applicable as when running straight ahead. This requirement is rendered as simple as possible, in the majority of cases, by passing the brake operating rods or levers through the center of the steering knuckle pin in a vertical direction, and in some cases, through the steering knuckle in a horizontal direction.

Fig. 61 shows the front-wheel brakes of the Spyker car, made in Holland. In this, the brake itself is of the internally expanded type and much like any other internal expanding brake, except for its operation. This is effected by a cam supported from the inner part of the wheel hub, and operated by a lever. This lever in turn receives its motion from a pin passing through the center of the vertical knuckle pin, which is worked from below by means of a bell crank and a cross lever placed underneath the axle, but not shown in this sketch. It might even be cable operated, as is the case with the Thames brakes shown at Fig. 62. These latter are hung on the hub of the wheel and thus made effective through the combination of cable operation and location on the hubs. This brake, too, is like any

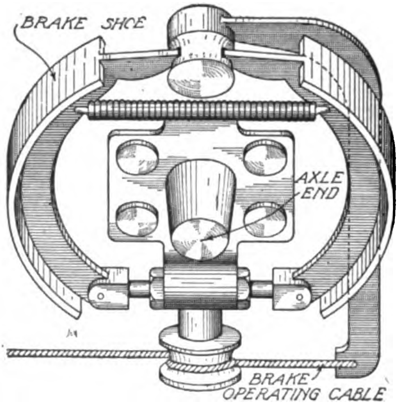


Fig. 62. Thames Front-Wheel Brake

other cam-expanded internal type of brake, the cable operation being the feature.

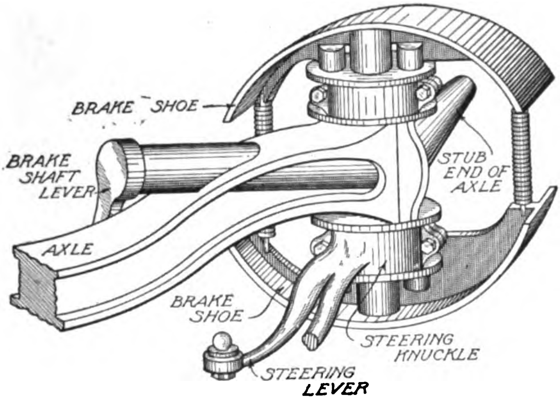


Fig. 63. Newton-Bennett Front-Wheel Brake

The Newton-Bennett brake, shown in Fig. 63, is on an English car, and has the brake shoes set horizontally instead of vertically.

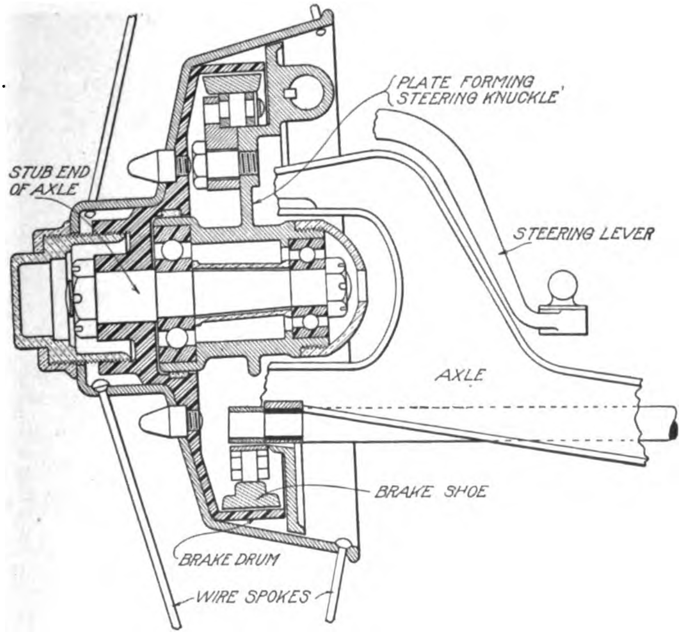


Fig. 64. Vertical Section of Crossley Front-Wheel Brake

A large boss on the axle forms the bearing for the operating shaft, which is actuated by means of a lever. Inside of the knuckle, at the exact center of motion and rotation, this shaft terminates in a double cam, one half of which moves the upper shoe upward and the other forces the lower downward. These operating cams work on pins which pass through the center of the steering knuckle pin, so their action is not affected in any way by the turning of the wheels. The vertical springs joining the ends of the brake shoes, hold them normally away from the drums.

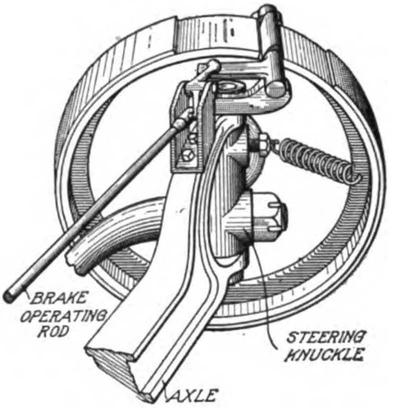


Fig. 65. Sheffield-Simplex Front-Wheel Brake

Unless the plane of the brake action and the plane of the wheel coincide, front braking will affect the steering action. In the Crossley (English) brakes shown in Fig. 64, this is cared for and the brakes are set well into the wheel, the plate forming the steering wheel being in the exact plane of the center of the wheel, while the brakes are situated in exactly the same plane. Thus, steering can have no effect upon braking nor braking upon the correct steering qualities. This brake has a series of four brake shoes, cam operated from within, each one being removable for replacement. Circular motion of a cross rod beneath the axle operates a toggle, which forces a central pin upwards and works another toggle. Between the two toggles, the four shoes are moved around slightly and forced against the brake drums. This is a well-worked-out design.

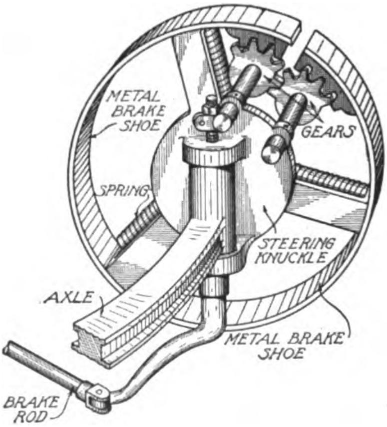


Fig. 66. Arrol-Johnston Front-Wheel Brake

A one piece shoe marks the Sheffield-Simplex (English) front brake, this being shown at Fig. 65. It is cam opened or spread from the top, this cam being worked through a lever, pivoted on the top of the steering knuckle and having a number of universal joints in it to insure universal action. A special U-shaped support for this mechanism is built up on top of the knuckle. The operating rod runs across the car, as will be noted in the figure.

The Arrol-Johnston brake-operating means includes the use of gears, Fig. 66, not noticed in any other form. The brake band is in one piece with teeth formed in the upper or cut end with which mesh a pair of partial gears, one gear with each half of the band. A lever below the axle turns a vertical shaft passing through the center of the knuckle pin. On the upper end of this, a bearing carries the ends of the gear shafts, one of which is operated from the vertical shaft. This operates the other through the medium of the gear teeth.

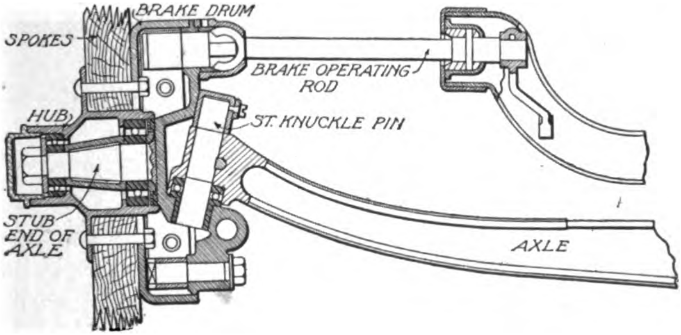


Fig. 67. Argyll Front-Wheel Brake Operating from Main Frame

Quite a different arrangement is in use on the Argyll, a Scotch car, Fig. 67. This brake is operated from the main frame, not from the axle as was the case with those previously described. To make this operation possible, the brake-operating shaft is fitted with a universal coupling at each end, thus allowing either vertical or horizontal movement or both. The sketch shows a sectional drawing through the wheel, axle, and brake, all of the parts being so clearly shown that further explanation would be superfluous.

All these forms have considerable mechanical complication, at least they add to the number of rods, levers, shafts, bearings for shafts, etc. To gain the many advantages of the front brakes without these counterbalancing disadvantages, a French engineer, Rolland, has brought out a front brake operated by hydraulic action. Its application to the Rolland-Pilain car is shown in Fig. 68. The usual form of brake drum is utilized, but the shoes are comparatively small, and of full width. One of these works vertically upward while the other works downward. Each is moved by a piston between the two in the center of the steering knuckle pin, the movement being produced by a liquid forced in under pressure. In the illustration, the pipe for this liquid may be clearly seen entering the chamber in which the pistons are located. A pump driven from one of the engine shafts furnishes the force, this being thrown into action at will.

In short, the front brake has been unusually successful in actual practice, which is the only real test of any device. In view of this success one may look for a much further future expansion in its use, for, as skidding becomes better understood, devices to prevent it will become more in demand, regardless of cost.

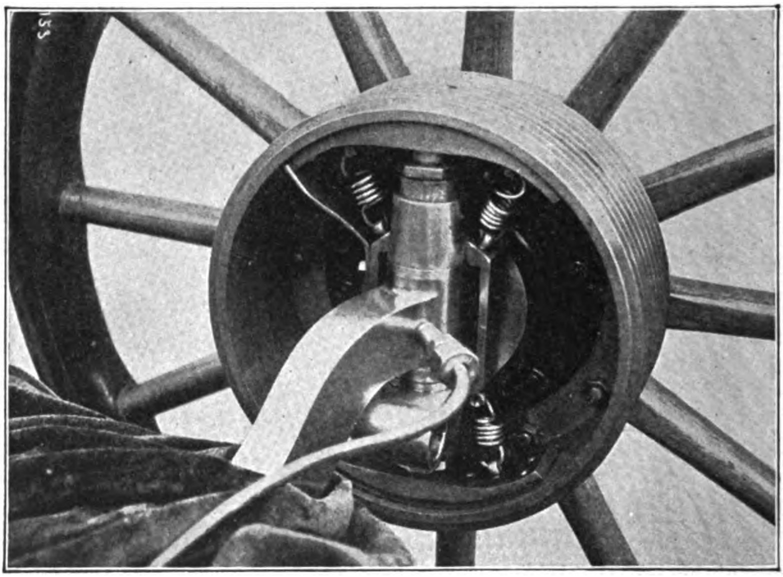


Fig. 68. Rolland Front-Wheel Brake within the Hub

The same may be said of any other device which will stop or even limit or partially reduce skidding, including all forms of anti-skid or non-skid tire treads, tire chains, tire grips, longer wheel bases, narrower steering locks, better weight distribution, and, finally, more sense in driving, with the avowed object of avoiding the dreaded skidding and its consequent dangers.

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